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Investigation of odourous gas emissions from meat and remaining plants

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1 INTRODUCTION

The Australian meat processing and rendering industries face increasing pressure from environmental authorities to minimise environmental impacts which can arise from the slaughtering and by-product processing operations. It is the area of atmospheric emissions, odours in particular, which is of greatest concern to the industry. Environmental regulators are being faced with increasing public dissatisfaction with nuisance odours, even in relatively remote locations, at a time when a consistent approach to odour regulatory policy is yet to be adopted.

While the meat industry has been active in the odour policy debate a more practical and fundamental problem has emerged concerning the optimum means of measuring the strength and detecting the presence of meat processing odours. Both dynamic olfactometry and GC-MS chemical analysis techniques are available and are widely used for odour concentration measurement, yet neither is ideal for detecting the presence of odour beyond a processing plant boundary nor for differentiating between meat processing odour and other types of odour.

As a result of these difficulties the Meat Research Corporation, now known as Meat and Livestock Australia (MLA), awarded a contract in September 1997 to CH2M HILL AUSTRALIA Pty Ltd (CH2M HILL) to investigate odorous gas emissions from meat processing and rendering plants (Project RPDA.303). This report describes the methodology, results and conclusions of the project.

CH2M HILL sub-contracted the Australian Nuclear Science and Technology Organisation (ANSTO) to carry out a major component of the project dealing with chemical and electronic nose technology detection methods. The ultimate significance of this work was such that this report has been co-authored by CH2M HILL and ANSTO.

2 PROJECT OBJECTIVES

The technical objectives of the project are as follows:

- To review analytical techniques suitable for odour measurement, highlighting advantages, disadvantages and costs;
- To develop a profile or fingerprint of odours emitted by characteristic processes and/or areas within processing plants by performing on-site sampling programs at several plants, and testing the samples using olfactometry and chemical analysis methods;
- To identify and quantify the Most Nuisance Compounds (MNCs) on each waste gas stream; and
- To identify and validate by an experimental program, a suitable technique (not olfactometry) for the measurement of the MNCs.

Further to these technical objectives it was a requirement of MRC that a summary of the project be reported in a 4-6 page format suitable for assimilation by industry and laboratory personnel. A single A4 page article suitable for inclusion in the "Envirofacts" bulletin is also required.

The essence of the technical objectives of the project is to develop a simpler and more practical method for identifying meat processing and rendering odours, including the compounds responsible for the typical character of these odours. The implication from the workscope documents prepared by MRC, confirmed in discussions with MRC management, are that a simpler gas chromatography analytical method and/or an 'electronic nose' technique should be investigated by the project team. As reported in Section 5, this has been the basis of the research methodology adopted by the project team.

3 CURRENT SITUATION

As mentioned in Section 1 odour is arguably the most problematic environmental issue facing the meat processing and rendering industry. While other environmental issues may also have significant cost implications for the industry (e.g. sustainable irrigation of effluent), odour problems have the potential to curtail or even shut down processing plants.

The environmental regulatory agencies have recently begun to interpret odour legislation, which tends to be written in terms of 'no odour at the boundary', in a quantitative manner. The resulting trend towards the use of olfactometry has resulted in odour performance guidelines for industry being expressed as a "maximum of X Odour Units (OU) at the boundary for Y percentage at the time". The regulators are currently struggling to develop a realistic and achievable quantitative odour standard for the meat industry. Not withstanding this trend towards quantitative odour policy, olfactometry has major deficiencies when used to assess ambient odour levels beyond plant boundaries or at receptor locations. Lower detection limits for olfactometry are typically 15 to 20 OU – far in excess the nuisance level for many unpleasant odours. Olfactometry is also not suitable for on-line monitoring of odour, a feature it has in common with all other analytical odour measurement methods. There are, as yet, no ambient odour abatement performance measurement devices designed to operate at a location remote from the source. The main applications for olfactometry are in the design and impact assessment areas. In such cases quantitative determination of current or future odour emission rates from industrial processes can be used to optimise the selection of odour control systems and, in conjunction with dispersion modelling, enable robust predictions of odour levels in the community to be made.

Chemical analysis methods of odour measurement, particularly using GC-MS, have been developed to the point where odour constituent compounds can be identified and quantified in the parts per billion range. This can be very useful in selecting odour treatment systems or for assessing likely health risks associated with exposure to odorous gases. Like olfactometry chemical analysis methods have practical limitations which restrict their use in the meat industry. For example knowledge of the chemical composition of an odour does not indicate odour character or strength, although with experience reasonable estimates can be made. The method is generally not suitable for ambient odour testing and, like olfactometry, does not lend itself to on-line odour monitoring. For certain compounds, such as hydrogen sulphide, monitors do exist but are only useful where the odour character and concentration are dominated by the compound in question. Chemical analysis using GC-MS can however differentiate between different types of odour provided that the differences are large and the concentrations of odorous compounds are within the detection range.

The rapidly developing Electronic Nose technology has been successfully developed for a wide range of industrial applications. To date very little effort has been directed at meat processing or rendering emissions. Most research has centred on process quality control such as monitoring the source of olive oil, in the ageing of cheese, in the detection of off-odours in fresh meat and fish, and the detection of rancidity in edible oils.

There has been no previous attempt to relate studies by olfactometry, chemical analysis and Electronic Nose in this field of odour study, but it is worth noting in passing however that a

4 KEY ASSUMPTIONS BY THE PROJECT TEAM

In developing a research methodology for this project the project team drew on the findings of team members' previous work in this area. Certain assumptions were made which were critical in maximising the chances of success of the project.

The fundamental hypothesis of the project was that key odorous compounds could be found which characterise meat industry odours and differentiate them from other types of agricultural and industrial odours.

To test this hypothesis the project needed to:

- determine the identity of these compounds (the MNCs) for all sources within meat processing and rendering plants; and

- develop a correlation between concentrations of the MNCs and the measured odour concentration (using olfactometry).

If a strong correlation could be found it would indicate the value of focusing on the MNCs as a primary means of developing an alternative odour measurement tool for meat industry odours. A simple method for the introduction to a Gas Chromatograph of volatile gases at ppb levels has been developed recently. The method, known as solid phase micro extraction (SPME) is still in the development phase but shows great promise for the detection and quantification of significant chemical odorants in gas streams. An evaluation of this technology has been included in this study.

Work over the past several years by Dr Stone involving a gas chromatographic procedure based on the US EPA TO-14 method (using a non-polar chromatographic column, and adaptations for the detection of low molecular weight sulphur compounds) have identified that sulphurous compounds such as hydrogen sulphide, methyl mercaptan, dimethylsulphide and dimethyldisulphide, in addition to branched low molecular weight aldehydes, are usually the most significant chemical odorants in odours from meat rendering and starch processing. This work found that meat rendering odours contain in addition heterocyclic compounds, amines and unsaturated low molecular weight hydrocarbons and nitriles related to the aldehydes. It is notable in passing that odours arising from decomposing organic matter such as in putrescible waste landfills contain a very different suite of volatile organic compounds. There is usually a strong correlation between the odour measured by olfactometry (in OU) and the concentrations of significant chemical odorants found, expressed as chemical odour units (COU). This methodology has been reviewed in the monograph; "Odour Minimisation Manual for the Meat Processing Industry", and it is an expectation of this study that similar correlations would be found.

Previous work by others on rendering odours is limited. Similar sulphurous and aldehydic compounds, and amines were identified in work by Bailey performed in the late 1970s (cited in "Odour Minimisation Manual for the Meat Processing Industry", section 1.3) using a polar chromatographic column.

Other work by Dr Stone has demonstrated advantages in using both polar and nonpolar columns for the analysis of certain polar odorous organic compounds, and it was therefore proposed to assess both types of analytical column in this study.

Critical to the success of this project was the selection of representative plants from which to source all odour samples for the project. It will be shown in Section 5 that the research covered a wide range of abattoirs and rendering plants during the course of the project.

5 RESEARCH METHODOLOGY

The research methodology proposed by CH2M HILL was based on odour characterisation using dynamic olfactometry and GC-MS analysis. The methodology was amended early in the project, with the concurrence of MRC, to include the use of electronic nose instruments which are now commercially available. The project objective of developing a simple detection method for meat industry odours did not change as a result of this decision, as it was felt that Electronic -Nose technology offered the potential for such a method in the future.

The project methodology is described in the following sections.

5.1 PARTICIPATING PLANTS

A total of five abattoirs or rendering plants took part in the project, providing the project team with access to a variety of processing operations at which odour sampling and subsequent analysis could be carried out.

The five plants were chosen by MRC after consultation with the project team. It is a condition of MRC that the identity of the plants not be disclosed in this report. It is, however, necessary to describe each of the plants so that the research results can be interpreted and discussed with maximum effectiveness. Two of the plants are regional abattoirs and include an integrated rendering plant to process fresh by-products from the kill floor. A small amount of external material is also rendered at each plant. The remaining three plants operate as service rendering facilities and are not associated with any particular abattoir. Each of these plants processes a variety of raw materials. A brief description of each plant follows:

Plant A:
A large sheep abattoir, processing for the export market. A single continuous cooker processes fresh material plus some imported chicken offal and blood. A biofilter is used for odour control;

Plant B:
A large regional beef abattoir where fresh by-products are processed in two batch cookers equipped with an afterburner for odour control;

Plant C:
A large service renderer with high and low temperature processes. Odour abatement consists of thermal destruction of non-condensable gases in a coal-fired boiler and dispersion of other air streams through tall stacks;

Plant D:
Another large service renderer which receives a full range of material, including fish waste. High temperature continuous and batch cookers are used. Non-condensable gas treatment uses afterburning. Biofiltration is used to treat other process air; and

Plant E:
Slightly smaller than Plants C and D but still a substantial operation. This plant uses biofiltration for odour treatment.

5.2 ODOUR SAMPLING AND OLFACTOMETRY

Between 4 and 10 samples of odorous process air were collected from each plant, on each of two separate occasions. A total of 55 samples were collected.

The objective of the sampling work was to produce representative samples for each of the three analysis methods, with the emphasis on odour characterisation. In the majority of cases air flowrate information was not gathered by the team. As a result it is not possible to derive odour emission rate data from the project results. With hindsight and knowledge of the odour problems facing many Australian meat processing plants it would have been desirable to expand the project workscope to include this additional work.

All samples were transported to CH2M HILL's dynamic olfactometry laboratory for testing within 24 hours of sampling. After testing the residual sample volume was couriered to ANSTO where GC-MS analysis was performed as soon as possible thereafter, usually on the same or, when necessary, the following day. All samples were collected in single use Nalophane sampling bags, thereby eliminating any risk of cross contamination.

Olfactometry testing of the samples was carried out using an OLFACTOMAT (type n-2) to the European CEN standard for odour measurement (CEN/TC264/WG2/N222/e), which, with minor amendments, has become the preliminary draft Australian Standard Method. Caution is recommended when comparing the results of this project to data derived from other methods of olfactometry testing, as other testing methods tend to produce lower and less consistent results.

5.3 GC-MS ANALYSIS

The GC-MS analysis was carried out under the supervision of Dr David Stone, to the method which he developed specifically for odour analysis. The method involves absorption in adsorbtion tubes directly from the bagged sample, and thermal desorption into the GC-MS instrument enabling typically 60 compounds to be identified and quantified in parts per billion by volume.

A known volume of each sample (usually 0.1-0.5 litre) was passed at 50ml per minute through a stainless steel adsorption tube filled with Tenax TA cooled to -78°C with powdered dry ice. Each tube was desorbed at 290°C for 2 minutes using helium gas into a glass-lined stainless steel cold trap packed with Tenax. The cold trap was maintained at -60°C during the desorption of the sample tube and then heated to 250°C during 20 seconds. The sample passed to a VG TRIO-1 Gas Chromatograph-Mass Spectrometer (GC-MS) system containing either a nonpolar DB-5 (30m/0.25mm/0.5µm) or polar DB-1701 (30m/0.25mm/0.25µm) analytical column. The column was maintained at 30°C for 3 minutes while the head of the column was maintained at -60°C for the first 2 minutes to focus the sample cryogenically. The oven was then programmed to increase to 50°C at 5°C per minute, and then immediately to 180°C at

10°C per minute. Compounds are eluted reproducibly from the column, and a software package presents the data as a chromatogram.

The compounds were identified by comparison with the NIST (USA) library of mass spectral data. Assignments were confirmed where possible by desorption of tubes spiked with standards prepared from the pure compounds. Hydrogen sulphide and methyl mercaptan were obtained as compressed gases diluted in nitrogen (10 ppm) while the other sulphides were obtained as neat liqids from Polyscience Co. (USA) with the exception of dimethyl disulphide which was obtained from Tokyo Kasei Co.(Japan). The aldehydes and alkenes were obtained from Alltech Associates (USA). Calibration curves were obtained for each compound, and this data provided the basis for the calculation of the amount of each substance. Several hydrocarbons, and oxygenated compounds were chosen from the list of those positively identified to serve as calibrants for the others of their group for which standards were not available. No reference compounds were added to the bags or the tubes before analysis. One sample in each batch of 4 to 6 were performed in duplicate.

This procedure is not universal in application for all gases and volatile organic compounds (VOCs), as there are inherent limitations for particular chemical groups. Many odorous VOCs are polar, and mixtures of odorous compounds therefore require careful selection of analytical methodology to maximise the information obtained from the chromatographic analysis. In general polar chemical compounds (ie. volatile fatty acids), some of which may be water-soluble, are poorly adsorbed onto most adsorbents (including Tenax) and require a special GC column with a very polar film for satisfactory analysis. Conversely, non polar compounds such as petroleum hydrocarbons and chlorinated hydrocarbons give optimum performance with standard adsorbents and nonpolar capillary columns, but are poorly separated on a polar column. Consequently several analyses may be required to determine most of the components in the mixture, ie volatile amines require a relatively non polar column with an unusually thick chromatographic film but sulphur compounds a thin film. It is not possible to obtain information on all components in a single analysis but a careful choice of two columns will often provide data for all the major compounds of interest.

An additional component of the analytical work involved the adoption, if possible, of a simpler GC or GC-MS method, and the comparison of this method's results with those derived from the more comprehensive GC-MS method. Therefore certain samples were introduced to the gas chromatograph by the Solid Phase Micro Extraction (SPME) technique using a Supelco Co. (USA) device containing either PDMS (silicone polymer film) or Carboxen (carbon particles) coated fibres equilibrated for 10 minutes with the gaseous sample and then desorbed directly for one minute into the GC injector in the splitless mode. This sample introduction method is simple and cheap and completely eliminates the need for specialist sample concentration equipment. It is possible to use this technique with any standard gas chromatograph or GC-MS, making it possible to perform tests in remote rural laboratories.

The data are presented in a spreadsheet for each sampling day, the analytical units are parts per billion (volume). Most-Nuisance Compounds (MNCs) are determined from the rank according to greatest chemical concentration of each compound or *more usually* from the rank according to greatest Chemical Odour. A Chemical Odour Unit (COU) is obtained by dividing the measured concentrations of each odorant compound (in ppb) by its threshold

concentration (in ppb). A compound with a proportionally larger COU value contributes more to the overall level of odour in a gas mixture than a compound with a lower COU. The sum of individual calculated COUs of as many components as can be reasonably determined in an emission yields the Total COU for a gas mixture. The sum of the chemical odours should be equivalent to the odour of the mixture in the absence of significant odour masking or enhancement effects.

In cases where the chemical odour for samples from the same plant (or even different plants) is dominated by several strong odourants, the MNCs, there is likely to be a good correlation between the calculated Total COU and the odour determined by dynamic olfactometry. It may be possible in addition then to estimate the odour (in OU) for similar samples from the concentration of the MNCs found. This hypothesis is based on the premise that all of the important contributors to the odour are identified and measured successfully, since a poor correlation between COU and OU/m^3 would indicate that compounds other than the identified MNCs are also significant. It is one of the aims of this project to identify the MNCs of rendering odour and demonstrate that they can be used to estimate the strength of the rendering odour. The project team determined that a measure of the validity of the COU model as the means of verifying MNCs is the correlation between total COU for the MNCs and olfactometry-based concentration of the sample (Odour Units per cubic metre) for a suitably large related set of samples. In practice however, the samples are analysed in small sets pertaining to a particular plant on a single day, and the correlations will be performed on these subsets of the data.

Upon identification of likely MNCs, the requirement for odour thresholds for each, to permit the most accurate estimate of Chemical Odour, in turn required the determination of these thresholds in most cases. This was due to the unreliability of much of the published threshold data or the absence of threshold data for several of the key compounds under investigation. Samples prepared from pure compounds were subjected to both olfactometry and GC-MS analysis. This provides threshold data for NMCs identified in the tested samples, acquired by the same instrument and methodology used to determine the odour strength of each of the same tested samples. This increases the validity of the method applied here to establish whether a correlation exists between an Odour measurement of a sample, and chemical analysis data as a function of odour thresholds for that sample.

5.4 ELECTRONIC NOSE TESTING

The term "electronic nose" is used to describe a range of sensor-based instruments which are now in commercial use in a variety of applications. In simple terms the technology uses clusters of chemical sensors which each respond to the presence of chemical compounds in a liquid or gaseous sample. By interpreting the pattern of the individual responses from a multiple sensor instrument it is possible to differentiate one substance from another, and even different concentrations of the same substance. Electronic nose devices are able to provide sufficient qualitative information to enable their use in quality control applications in food and beverage industries, but cannot usually be used in a quantitative manner. The project team judged that this technology may be suitable for differentiating meat industry odours from other commonly occurring odours. For this reason the project was expanded to enable a preliminary evaluation of this technology.

The services and expertise of the Australian Food Industry Science Centre (AFISC) were called upon to assist in the work. Dr Brian Young and Mark Alexander provided access to an Aromascan (UK), Aromascanner Electronic Nose instrument at AFISC which utilises conducting polymer sensors. A major drawback of this instrument is the sensitivity of the sensors to water. A second instrument, the Alpha M.O.S (France), FOX 4000 Electronic Nose, was also made available later in the project through the assistance of the Analytical Equipment Company (Vic). The latter instrument utilises metal oxide sensors which are not water sensitive and give equivalent or better responses than conducting polymer sensors. AFISC has opted to continue with the Alpha MOS in preference to the Aromascanner subsequent to this work.

Of the 55 odour samples tested by both olfactometry and the GC-MS method, a total of 19 were also tested at AFISC. These samples represented those collected during the second sampling visit to four of the five plants (A-D). In addition 9 samples of pure chemical compounds used for the odour threshold determination, plus three synthetic odour mixtures and dilutions of a single odour sample at 4 different concentrations were analysed at AFISC.

The methodology used to assess the performance of the electronic nose instruments involved correlation between instrumental output, presented as two principle components in cartesian space, and each of the OU/m^3 and COU values for sets of samples from different plants previously mentioned. A strong correlation between these parameters would indicate the potential of this technology in meat industry odour applications.

6 RESULTS AND OBSERVATIONS

6.1 OLFACTOMETRY

The dynamic olfactometry results for the 55 samples taken from the 5 plants on 2 occasions, and 14 assorted pure MNCs and synthetic render odour mixtures are presented in Appendix 1, organised by plant and date, while an example (plant E) is presented in Table 1. The composition of the synthetic mixtures will be discussed in the chemical analysis section. The pure chemicals include the four most nuisance sulphur compounds, four most nuisance aldehyde compounds representing the range of molecular weights usually found (4 to 7 carbon atoms), and a representative amine (methylamine) at a concentration typical of the sum of amines usually found.

Table 1: Example of Olfactometry Results (Plant E)

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m^3)
Inlet to dryer biofilter	522	37,000
Inlet to non condensable gas biofilter	523	220,000
Inlet to factory air biofilter	524	21,600
Outlet to dryer biofilter	525	19,100
Factory air in raw materials building	526	2,050
Butanol reference gas	ref19971017	753 (66 ppb)

It is noteworthy that the olfactometry results show a very wide range of odour concentrations is possible in meat processing plants, ranging from near-ambient odour levels in abattoir slaughter floor ventilation air to extreme odour levels in cooker vapours and non-condensable gas streams. It is stressed at this point that, except in the broadest terms, the olfactometry results from one plant are not directly comparable to another plant. This is due to a combination of wide differences in processes and foul air collection systems. For this reason a plant with higher recorded concentrations of odour would not necessarily generate odours at a greater rate than other plants with lower odour concentrations.

6.2 CHEMICAL ANALYSIS

A typical chromatogram for a moderate odour strength sample from Plant C, is presented as Figure 1, together with a chromatogram obtained from a synthetic mixture of the identified compounds. The origin of the synthetic mixture and its purpose will be discussed further below.

The Chemical Analysis results for the 55 samples are presented in Appendix 2, organised by plant, date and analytical column used, either nonpolar DB-5 or polar DB-1701. Table 2a contains the results for Plant E, sampled 17 Oct 1997, analysed with the nonpolar column,

Figure 1.

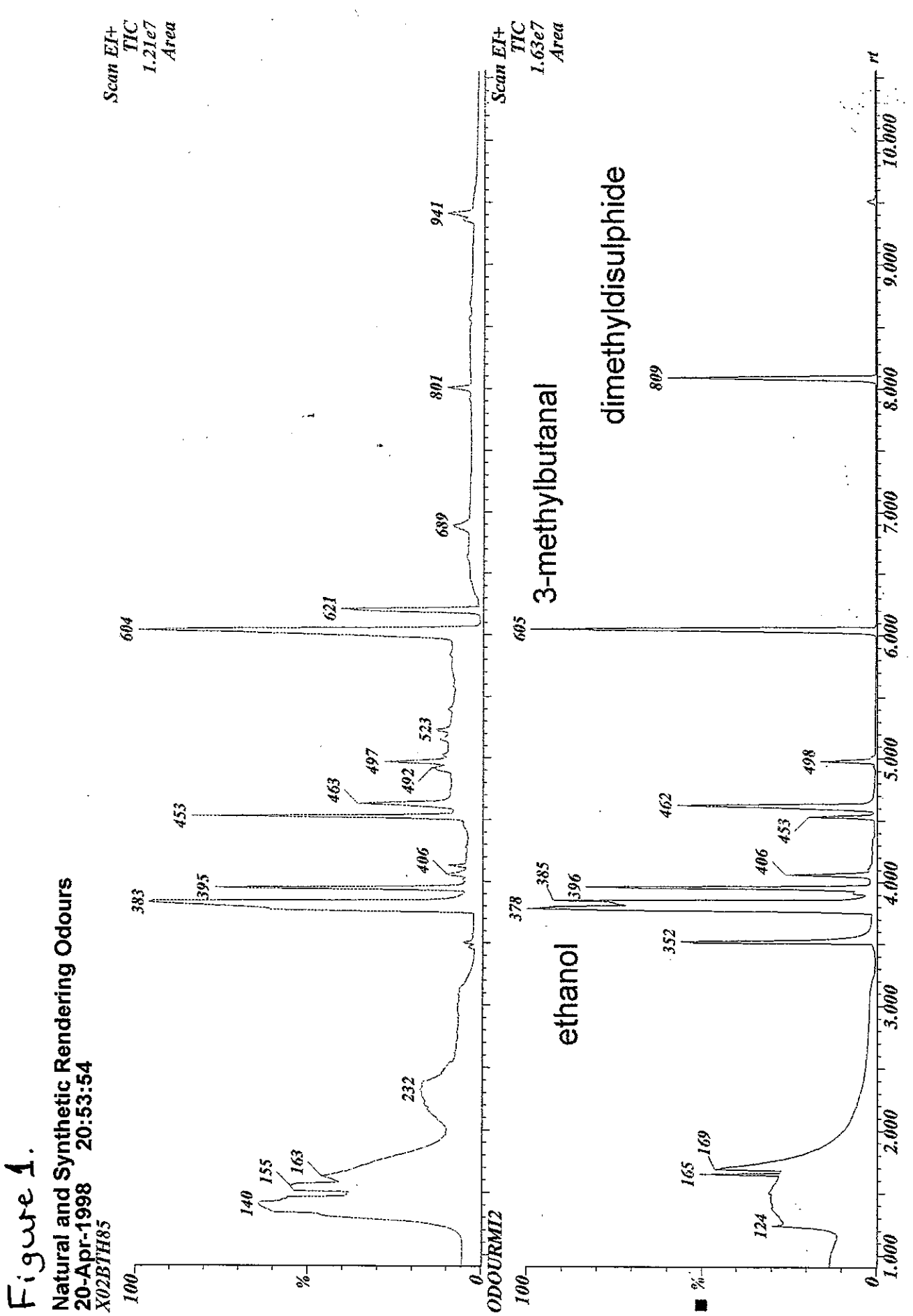

Natural and Synthetic Rendering Odours
20-Apr-1998 20:53:54
X02BTH85
Scan EI+
TIC
1.21e7
Area
ODOURMI2
Scan EI+
TIC
1.63e7
Area
3-methylbutanal
dimethyldisulphide
ethanol
%
rt

Table 2A. Volatile Organic Components from Meat Processing Plant

Plant E	Drier	Non	Factory air	Drier	Raw
nonpolar column		condensables		Biofilter (out)	materials
17-Oct-97					
component	concentration				
hydrogen sulphide	25.2	29,350	116	50.5	29.1
carbonylsulphide	327	9,531	82.6	141	13.1
sulphurdioxide	2.2	13.6	0.6	0.9	0.3
methylmercaptan	103	15,424	507	<0.1	90.0
dimethylsulphide	0.6	139	3.9	4.7	4.7
carbondisulphide	238	380	18.3	411	0.6
ethylmercaptan	<0.1	831	2.0	<0.1	<0.1
i-propylmercaptan	<0.1	27.9	<0.1	<0.1	<0.1
propylmercaptan	1.3	9.8	<0.1	<0.1	0.1
dimethyldisulphide	1.3	77.4	2.6	1.0	0.8
dimethyltrisulphide	<0.1	<0.1	<0.1	<0.1	<0.1
acetaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1
propenal	150	29	19.1	14.5	7.6
2-butenal	53.1	24.8	4.1	4.9	3.7
butanal	228	58	5.3	3.2	2.2
2-methylpropanal	211	1,720	249	11.4	4.5
2-methylpropenal	29.4	13.8	4.4	6.8	3.7
2-methylbutanal	83.0	3,135	289	4.7	1.1
3-methylbutanal	124	3,839	357	7.7	4.5
pentanal	904	628	84.7	274	8.0
hexanal	597	551	55.1	273	15.0
heptanal	408	303	22.8	78.0	10.5
methanol	396	302	122	106	92.4
ethanol	4,318	1,439	492	95.0	468
i-propanol	29	394	83.7	19.2	35.7
propanol	18	124	20.1	5.1	12.3
t-butanol	5.0	15.2	4.1	2.3	0.5
i-butanol	12.2	38.2	6.5	2.7	1.0
2-butanol	4.4	82.1	4.4	1.0	0.8
butanol	62.7	72.5	6.0	14.5	1.8
3-methylbutanol	43.5	37.3	6.2	5.2	2.4
acetone	1,136	1,805	460	312	109
2-butanone	192	198	45.1	62.8	5.3
3-buten-2-one	129	18.2	6.9	1.6	10.8
2,3-butanedione	126	142	25.4	2.3	16.7
methylisobutylketone	53.0	264	23.0	13.4	10.5
ethylacetate	6.2	39.6	5.0	6.9	3.0
benzene	69.1	96.1	3.9	96.8	2.1
toluene	131	283	81.2	96.9	28.3
ethylbenzene	27.0	102	3.4	11.9	2.4
m,p-xylene	37.8	166	7.5	9.3	4.6
o-xylene	14.6	45.7	2.6	4.8	1.9
dichloromethane	24.7	10.1	53.2	3.2	43.6
chloroform	12.6	48.4	6.9	4.4	9.0
1,1,1-trichloroethane	11.0	4.9	1.2	1.8	2.0
trichloroethylene	11.3	16.0	8.8	2.8	1.2
tetrachloroethylene	1.0	0.3	2.9	0.2	2.7
methylcyclopentane	3.8	21.0	23.8	30.7	5.5
methylcyclohexane	3.2	66.9	30.5	37.3	1.4
cyclohexane	7.7	51.2	35.5	43.1	7.5
hexene	881	8.0	6.4	1,198	9.8
heptene	813	39.1	14.2	1,401	5.3
octene	710	23.8	2.0	884	4.3
nonene	168	7.1	1.4	452	2.1
Sum Sulphurs	699	55,783	734	609	139
Sum Aldehydes	2,789	10,302	1,090	678	61
Sum others	7,767	5,891	1,580	2,191	893
TOTAL (ppb)	**11,254**	**71,977**	**3,403**	**3,478**	**1,092**

while Table 2b reports the results for the same set of samples analysed on the polar column. The left hand column in each case is a list of identified chemical compounds grouped by type, beginning with sulphurous compounds, then aldehydes, alcohols, ketones, esters, aromatic hydrocarbons (BTEX), chlorinated hydrocarbons and unsaturated hydrocarbons. It is not possible to identify all compounds found using the nonpolar column with the polar column also, thus requiring a different list in each case. The rows below the last chemical in the list are selected totals of the various components found to be of importance in previous work (but clearly useful in this work also, as subsequent analysis will demonstrate). Sum Sulphurs is the numerical sum of the first 11 (or 8; Table 2b) compounds, hydrogen sulphide to dimethyltrisulphide, while Sum Aldehydes is the sum of the next 11 (or 12) compounds down to heptanal or octanal. Sum Others is the sum of the remaining compounds and Total ppb is the sum of all components. The other columns contain lists of concentrations in parts per billion (ppb), for each of the plant units described at the top of the column.

Each set of 10 samples was analysed on the nonpolar column, but only eight sets were analysed using the polar column due to time restraints. The first set of data for plant D appears on 2 sheets because of the extended number of samples taken at this plant on that occasion. Together, the analytical data provides an accurate fingerprint of the chemical compounds responsible for the odour at the five rendering plants studied. There are subtle differences between the 2 sets of analytical data not the least being the consistently lower values for the polar column. This however is an artefact of the experimental process, as more time elapsed in the analysis by the (non-standard) polar column in this case, which was the first data set, than for any of the others following. What is of greater significance is the notable eases with which the polar column identifies octanal and higher aldehydes, dimethyltrisulphide and other higher molecular weight polar compounds, compared with the nonpolar column which, however, is a better choice for all low molecular weight compounds. This is a general observation, not unusual in this case, as the polar column selectively separates the moderately polar odorous aldehydic chemicals from the less odorous nonpolar hydrocarbons, but gives poor performance at low molecular weights where all of the hydrocarbons elute without adequate separation, obscuring many volatile odorants.

A group of compounds often encountered in meat cooking off-gas streams are the simple amines including dimethylamine and trimethylamine. It is difficult to quantify, or even identify absolutely these compounds, but they are often present at low part per million levels in sources such as the press air (plant B), the cooker and Incinerator gases (plant D), and the noncondensible gas (plant E). There are small amounts of the same gases in the scrubber inlet and outlet (plant C) and the exhaust air (to biofilter) from plant A. These sources are often the strongest odours in the respective plants which may indicate that amines are detected by GC-MS only in strong sources, whereas in all likelihood the amines are spread throughout the plant just as the sulphur and aldehydic compounds are. It has not been practical to include these compounds in the Tables of data but their clear presence necessitates inclusion in any odour assesment or synthetic render odour mixture.

Two samples of significantly different odour strength were subjected to both the normal thermal desorbtion GC-MS method and the experimental SPME GC-MS method using a Carboxen fibre. The chemical analysis results for this test are compared in Table 3, where concentrations for a selection of ten most nuisance compounds and the percent difference between the methods are presented. Sample 1, which had an odour strength of ca 8,500

Table 2B. Volatile Organic Components from Meat Processing Plant

Plant E	Drier	Non	Factory air	Drier	Raw
polar column		condensables		Biofilter (out)	materials
17-Oct-97					
component (ppb)	concentration				
hydrogen sulphide	14.3	9,894	70.0	<0.1	35.8
carbonylsulphide	184	1,475	40.9	37.4	2.8
sulphurdioxide	<0.1	<0.1	<0.1	2.6	1.1
methylmercaptan	20.2	4,396	143	9.7	25.7
dimethylsulphide	<0.1	123	<0.1	<0.1	0.5
carbondisulphide	<0.1	0.7	<0.1	62.6	<0.1
dimethyldisulphide	2.4	63.8	3.5	0.8	0.5
dimethyltrisulphide	2.2	73.6	6.2	0.6	0.3
acetaldehyde	27.7	28.8	6.9	6.1	3.7
propenal	5.1	12.0	2.9	0.9	0.0
propanal	<0.1	<0.1	<0.1	<0.1	<0.1
butanal	59.4	71.3	8.7	17.3	6.5
2-methylpropanal	148	706	137	5.3	2.1
2-methylpropenal	46.0	7.5	2.7	1.0	2.6
2-methylbutanal	72.4	552	126	11.2	1.3
3-methylbutanal	130	1,435	322	21.6	2.4
pentanal	281	96.6	15.2	46.2	7.9
hexanal	438	176	156	132	17.6
heptanal	345	111	31.8	10.3	15.2
octanal	35.4	35.3	7.9	35.7	16.2
methanol	58.2	70.5	98.1	55.1	61.5
ethanol	6,120	1,915	330	69.3	347
i-propanol	202	510	48.0	20.7	16.5
propanol	28.6	132	14.5	3.0	9.3
acetone	517	649	205	112	69.9
2-butanone	165	175	21.1	33.4	3.0
benzene	62.2	58.6	2.8	88.3	0.9
toluene	38.0	72.9	15.2	23.8	5.0
ethylbenzene	24.5	78.0	2.2	5.4	0.6
m,p-xylene	44.8	131	5.2	5.9	1.6
o-xylene	22.7	112	4.9	4.0	0.8
dichloromethane	45.0	3.0	20.1	106	17.5
chloroform	4.5	27.4	18.6	9.2	3.7
1,1,1-trichloroethane	6.5	2.6	2.2	1.1	1.5
Sum Sulphurs	223	16,026	264	114	67
Sum Aldehydes	1,588	3,230	817	288	76
Sum others	7,339	3,938	787	537	539
TOTAL (ppb)	**9,150**	**23,194**	**1,868**	**938**	**681**

Table 3. Comparison of Thermal Desorbtion and SPME sample introduction to GC-MS

Comparative SPME	**Sample 1**	**Sample 1**	% difference	**Sample 2**	**Sample 2**	% difference
nonpolar column	**TO-14 method**	**SPME**		**TO-14 method**	**SPME**	
component (ppb)		**carboxen fibre**			**carboxen fibre**	
hydrogen sulphide	101	<0.1	N/A	73,411	<0.1	N/A
methylmercaptan	80.0	1.3	1.67%	66,595	318	0.48%
dimethylsulphide	23.4	2.3	9.87%	2,072	58.6	2.83%
dimethyldisulphide	230	14.1	6.12%	3,976	171	4.29%
2-methylpropanal	**718**	**87.0**	12.1%	**66,826**	**681**	1.02%
2-methylbutanal	**1,213**	**285**	**23.5%**	**102,682**	**3,046**	**2.97%**
3-methylbutanal	**1,809**	**582**	**32.2%**	**189,673**	**5,693**	**3.00%**
pentanal	**89**	**24**	**27.4%**	**1,191**	**134**	**11.2%**
hexanal	52.7	11.6	**22.1%**	537	43	**8.04%**
heptanal	8.5	7.0	**82.9%**	143	42.1	**29.4%**
Sum Sulphurs	433	18	4.08%	146,054	547	0.37%
Sum Aldehydes	3,890	998	25.6%	361,052	9,639	2.67%
TOTAL ppb	**4,323**	**1,015**	**23.5%**	**507,107**	**10,187**	**2.01%**
COU	**1,201**			**287,868**		
OU/m^3	**5,100**			**860,000**		

OU/m^3, demonstrates the utility of the method in identifying and approximately quantifying eight of the ten MNCs selected. This has been easily achieved at an odour strength relatively low for these meat industry plants. The poor results for hydrogen sulphide and methyl mercaptan are to be expected given the low boiling points of these compounds (which are gases at room temp.) and the consequent relatively low capacity for them on the carbon adsorbent. Aldehydes present in the sample at 10-100 ppb or more are easily detected however and the SPME method gives a response which is 20-30% of the values attained by the normal method. Sample 2 had an odour strength of ca 860,000 OU/m^3 , which is a little higher than most of the high strength meat industry samples examined in this study. It is to be expected that stronger samples give higher readings , but it is apparent from these data that the relative increase in calculated concentrations for the SPME introduction method is much less than that obtained by the usual method. This is not necessarily a limitation, but clearly indicates that a greater dynamic range of sample concentrations can be measured by SPME compared with Thermal desorbtion before the need to dilute strong samples is unavoidable. In fact a closer examination reveals that the increases vary, with smaller increases mainly for the three aldehydes present at the 100 ppm level (SPME only 1-3% of normal) while the other components, present at low ppm levels, were recovered at levels closer to 10% of the normal method. In other data not presented here it is clear that a combination of a polar analytical column and the SPME introduction method utilising the PDMS fibre gives excellent data for higher molecular weight aldehydes, hexanal to decanal, and dimethyltrisulphide substantially free of any chromatographic interferences. This provides further options to an analyst using this simple technique to describe and quantify rendering odours. The conclusion is that the aldehydes characteristic of rendering odour may easily be measured by simple, inexpensive SPME gas chromatographic techniques which may be readily utilised with almost any existing gas chromatograph.

6.3 ELECTRONIC NOSE RESULTS

The electronic nose results, produced as a separate report, are presented in Appendix 5.

7 ANALYSIS OF RESULTS

7.1 OLFACTOMETRY

While the results of the olfactometry need to be evaluated in concert with the GC-MS and e-nose results in order to maximise their value, there are certain findings which can be made which may assist the industry address day-to-day odour problems.

The most obvious findings from the olfactometry results is that non-condensable gas streams have enormous potential to cause off-site odour nuisance if odour treatment systems of these streams perform suboptimally. For example, when odour concentrations up to one million Odour Units per cubic metre are possible, treatment efficiencies less than 99% could result in emissions having an odour concentration in excess of 10,000 OU/m^3. This assessment supports the need for high quality operation and maintenance systems for non-condensable gas treatment systems.

A second tier of odour sources within rendering plants is indicated, these sources generating moderate strength odours (10,000 to 20,000 OU/m^3) which usually require either treatment or enhanced dispersion. Such sources include blood dryers, and extracted air from cooker unloading operations and meal presses. Without centralised odour collection and treatment and/or dispersion systems these sources can lead to excessively high odour levels within rendering buildings and the consequent risk of fugitive odour emissions and nuisance. For the plants studied in this project the odour levels within the processing buildings were relatively low (1,000 to 2,000 OU/m^3) as a result of effective point source collection and treatment systems.

The final and perhaps most obvious finding of the olfactometry component of the project was that olfactometry was still the only odour assessment technique which measures 'true' odour levels, as perceived by the community. While its practical and cost deficiencies are acknowledged, olfactometry will continue to have a role where odour audits or odour minimisation is required.

7.2 CHEMICAL ODOUR CALCULATIONS

In order to identify the Most Nuisance Compounds (MNCs) responsible for rendering odour, and demonstrate whether the chemical analysis and olfactometric measurements correlate, it is necessary to calculate the chemical odour for each individual compound and sum the values to arrive at the Chemical Odour for each sample. It is also necessary to simplify the data before useful comparisons between sources and plants can be made.

Each concentration value reported in appendix 2 (of which there are nearly 4,000) is divided by the threshold odour value appropriate for the compound. This results in an equivalent set of Tables, an example of which is presented in Table 4, the data for Plant E (17^{th} Oct, 1997, nonpolar column) while the remainder are presented in Appendix 3. The data are no longer concentrations in parts per billion but dimensionless values (chemical odour units, COU). The second column from the left contains the odour thresholds used in the calculation, and those shaded have been determined as part of this project in order to improve the accuracy of the

Table 4. Calculation of Chemical Odour Units for Meat Processing Plant Odours

Plant E	Threshold	**Drier**	**Non**	**Factory air**	**Drier**	**Raw**
nonpolar column	(ppb)		**condensables**		**Biofilter (out)**	**materials**
17-Oct-97						
component		**Chemical Odour Units**				
hydrogen sulphide	0.25	101	117,401	466	202	117
carbonylsulphide	100	3.3	95.3	0.8	1.4	0.1
sulphurdioxide	9	0.2	1.5	0.1	0.1	0.0
methylmercaptan	0.35	295	44,068	1,449		257
dimethylsulphide	0.97	0.6	143	4.0	4.8	4.8
carbondisulphide	20	11.9	19.0	0.9	20.5	0.0
ethylmercaptan	1		831	2.0		
i-propylmercaptan	1		27.9			
propylmercaptan	1	1.3	9.8			0.1
dimethyldisulphide	1.76	0.7	44.0	1.5	0.5	0.5
dimethyltrisulphide	2.0					
acetaldehyde	3					
propenal	1	150	29.1	19.1	14.5	7.6
2-butenal	1	53.1	24.8	4.1	4.9	3.7
butanal	1	228	57.7	5.3	3.2	2.2
2-methylpropanal	0.54	392	3,185	461	21.1	8.4
2-methylpropenal	0.6	49.0	23.0	7.3	11.3	6.2
2-methylbutanal	0.3	277	10,451	963	15.7	3.5
3-methylbutanal	0.24	518	15,997	1,486	32.2	18.7
pentanal	0.5	1,809	1,256	169	547	16.0
hexanal	5.9	101	93.5	9.3	46.3	2.5
heptanal	0.7	559	415	31.3	107	14.4
methanol	1000	0.4	0.3	0.1	0.1	0.1
ethanol	1750	2.5	0.8	0.3	0.1	0.3
i-propanol	500	0.1	0.8	0.2	0.0	0.1
propanol	600	0.0	0.2	0.0	0.0	0.0
t-butanol	1270	0.0	0.0	0.0	0.0	0.0
i-butanol	80	0.2	0.5	0.1	0.0	0.0
2-butanol	50	0.1	1.6	0.1	0.0	0.0
butanol	40	1.6	1.8	0.2	0.4	0.0
3-methylbutanol	80	0.5	0.5	0.1	0.1	0.0
acetone	420	2.7	4.3	1.1	0.7	0.3
2-butanone	9	21.3	22.0	5.0	7.0	0.6
3-buten-2-one	20	6.5	0.9	0.3	0.1	0.5
2,3-butanedione	20	6.3	7.1	1.3	0.1	0.8
methylisobutylketone	100	0.5	2.6	0.2	0.1	0.1
ethylacetate	710	0.0	0.1	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.1	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.2	0.1	0.4	0.0	0.3
chloroform	150	0.1	0.3	0.0	0.0	0.1
1,1,1-trichloroethane	150	0.1	0.0	0.0	0.0	0.0
trichloroethylene	150	0.1	0.1	0.1	0.0	0.0
tetrachloroethylene	150	0.0	0.0	0.0	0.0	0.0
methylcyclopentane	150	0.0	0.1	0.2	0.2	0.0
methylcyclohexane	150	0.0	0.4	0.2	0.2	0.0
cyclohexane	150	0.1	0.3	0.2	0.3	0.0
hexene	25	35.2	0.3	0.3	47.9	0.4
heptene	25	32.5	1.6	0.6	56.0	0.2
octene	25	28.4	1.0	0.1	35.4	0.2
nonene	25	6.7	0.3	0.1	18.1	0.1
Sum Sulphurs	Sum Sulphurs	414	162,640	1,925	230	379
Sum Aldehydes	Sum Aldehydes	4,135	31,532	3,155	803	83
Sum others	Sum others	146	48	11	167	4
TOTAL (ppb)	**COU**	**4,695**	**194,220**	**5,091**	**1,200**	**467**
	OU/m^3	**37,000**	**220,000**	**21,600**	**19,100**	**2,050**
	ratio (OU/COU)	7.9	1.1	4.2	15.9	4.4

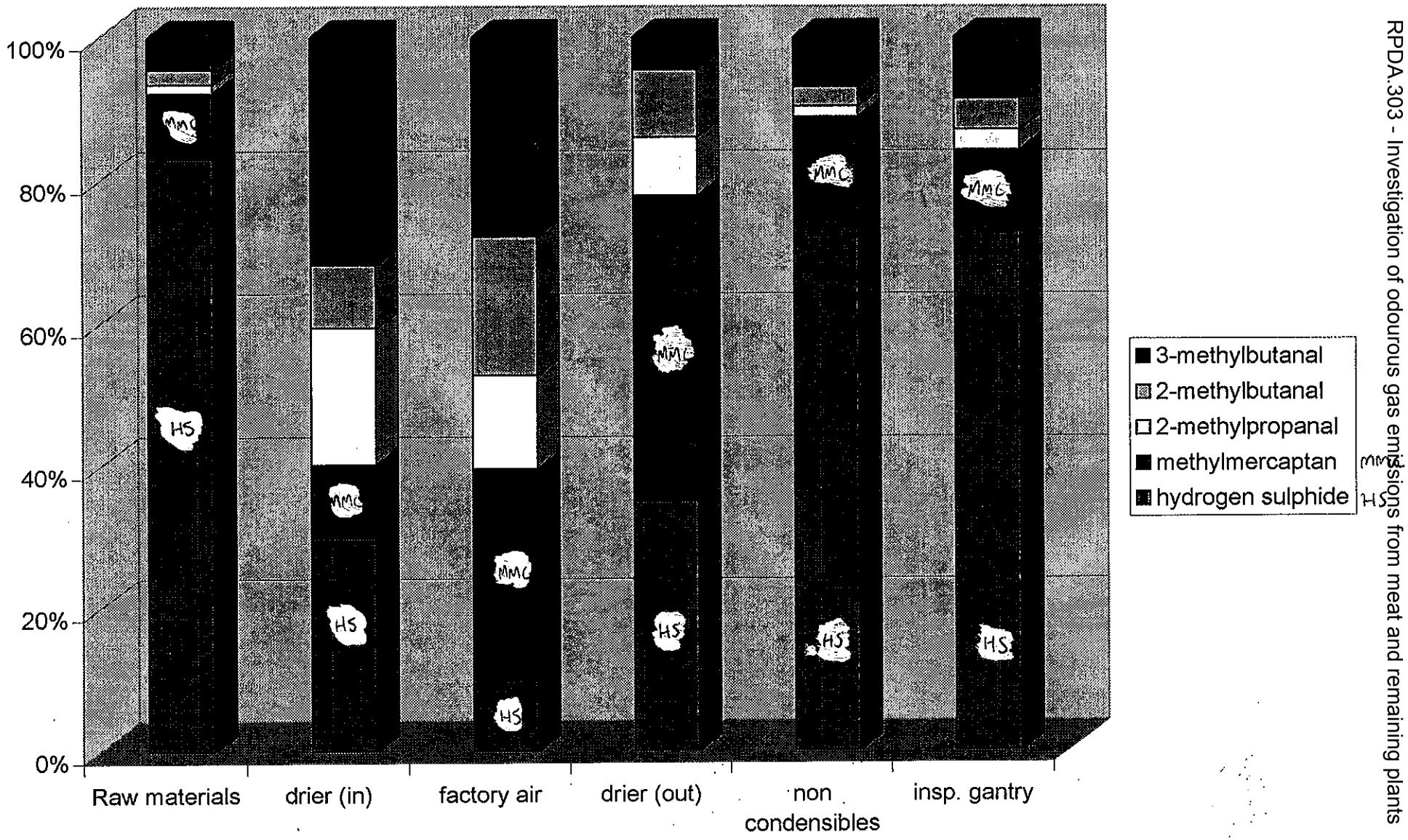
correlation. The remainder of the thresholds are from the literature or the nearest related compound reported in the literature. The COU data are presented with a maximum of one decimal place precision, and therefore any values less than 0.05 will appear as 0.0 in the Tables. Blank spaces in the Table result from concentrations less than the detection limit in the corresponding Table of concentrations.

The series of summations and other factors at the bottom of the page now includes the three chemical categories of summed values already discussed in section 6.2, a total chemical odour simply called the COU for the sample, the odour strength in Odour Units per cubic metre (from appendix 1), and the ratio of the OU and COU value. These ratios have been found through considerable previous experience to generally lie between 1 and 10, reflecting a tendency of the Chemical Odour model to consistently underestimate the Odour strength determined by the Olfaktomat. The significance of these numbers will be discussed in the next section.

An examination of Table 4 reveals a large number of compounds which have relatively high odour thresholds with result that more than two thirds of the values in the Table are zero or close to zero, effectively reducing the data set by 70%. The only significant values are generally either aldehydes or sulphur compounds with the exception of some ketones and alkenes. In the case of the Drier samples there are small but significant values associated with alkenes, but it is worth noting that these alkenes were the most significant compounds on the basis of concentration in the concentration data set (Table 2a). Because the odour thresholds of aldehydes and sulphur compounds are substantially lower than those of alkenes, the alkenes don't rank as Most Nuisance Compounds whereas the former compounds do, they are better odorants. Notice that similar fates befall the significant quantities of alcohols, ketones and alkenes in the other samples.

An examination of the Tables in appendix 3 reveals that the ten most significant odorants are consistently a mixture of aldehyde and sulphur compounds. It doesn't matter which of the plants you choose or whether you consider the polar or non polar columns. Both hydrogen sulphide and methyl mercaptan are usually in the top five the former is nearly always the greater of the two. Dimethylsulphide and dimethyldisulphide are always present in lesser amounts than the first two but often both in the top ten to 12 compounds. Of the aldehyde compounds, 3-methylbutanal, 2-methylbutanal and 2-methylpropanal are often the most significant, but one or more of the other 5 or 6 aldehydic compounds detected are often at similar or greater levels. A bar graph showing the relative importance of the 5 above-mentioned most significant odorants for Plant E (10^{th} Nov, 1997 nonpolar column) is presented as Figure 2. Hydrogen sulphide dominates several sources (the non-condensables, fugitives from the cookers and raw materials), while there is much less in the factory air and drier samples. It demonstrates that the relative importance of many of the sulphur and aldehydic compounds varies from source to source but as a class they are always dominant. Moreover, since the odour thresholds of all these compounds are close to or less than 1 ppb, they are all similar in odorant strength. It is thus a valid and effective procedure to sum the sulphur and aldehyde compounds and use these units to distinguish the samples from each other rather than attempt to plot all of the individual compounds. Thus the original data set of 50 or more chemical compounds identified in the chromatograms for each sample may be usefully reduced to 2 numbers, the sum of sulphur COUs and the sum of aldehyde COUs. Thus it may be observed that of the samples in Table 4, the factory air and drier samples are

Figure 2. Most Nuisance Compounds, Plant E, Nov 10,1997



dominated by aldehydes while the non-condensables and raw materials have sulphur compounds in significant excess.

7.3 CORRELATION BETWEEN ODOUR STRENGTH AND CHEMICAL ODOUR

As explained in the methodology section the degree of correlation between the Odour and Chemical Odour is an indication of the degree of certainty that the MNCs have been identified and properly quantified. Each of the Tables in appendix 3 has the calculated Chemical Odour (in COU), the Odour strength (in OU/m^3) plus a ratio of the two numbers occupying the bottom three rows of the Table. A scatter plot of the COU for the nonpolar column vs the corresponding OU data is produced in each case and the linear regression is determined. The results for both days at each plant are presented by plant and date in appendix 4. Tables where most of the OU/COU ratios are similar in magnitude produce linear fits with very high regression coefficients (values of 1.0 represent a perfect linear fit), the slope of the line being close to the median of the OU/COU ratios.

Plant A (6th Nov, 1997) has a regression coefficient of 0.99 and a slope of 2.8, while the second set (18th Dec, 1997) has a larger slope and a coefficient of only 0.6, largely because of a serious discrepancy between the OU and COU values for the plant air to and out of the biofilter. These values are in line with expectation and indicate that there is a good correlation. Clearly therefore the MNCs have been adequately identified and quantified.

Plant B (19th Nov, 1997) fails to give a satisfactory correlation unless the Press air sample is removed from the analysis. The second set of data (19th Dec, 1997) has a similar difficulty though the Press air sample doesn't upset the regression as severely. When the seven samples from both days, not including the Press air, are considered together, the regression coefficient is 0.71 and the slope is 0.70. This indicates that there is still a difficulty with these samples. Clearly not all of the MNCs are considered in the calculation. The most likely source of error is the large amounts of several amines in the press air samples, with possibly lesser amounts in other samples.

Plant C (26th Nov, 1997) by contrast has near perfect linearity, a regression coefficient of 0.99 and a slope of 5.9 while the second set (4th Mar, 1998) had a coefficient of 0.99 and a slope of 4.2. A plot of all Plant C data gives a regression of 0.98 with a slope of 4.45. The MNCs have been successfully identified in this case, see comments on Plant A.

Plant D (15th Nov, 1997) which involved 10 samples has a regression coefficient of 0.9998 and a slope of 1.1, while the second set (23rd Jan, 1998) has a lower coefficient (0.86) but the same slope, when the Incinerator sample was left out of both regression analyses. This sample contains a great amount of amine similar to the Press air samples of Plant B which caused some difficulty with the correlation of that plant's data. See comments on Plant B.

Plant E (17th Oct, 1997) has a regression coefficient of 0.76 and a slope of 4.7 when the high odour strength (amine rich) non-condensables sample (220,000 OU) is excluded from the calculation. The second set has an extremely strong sample (8,700,000 OU) which gives the regression an unreliably linear coefficient though the COU value (194,000) is clearly a great deal short of reality. These samples were diluted before analysis which introduces errors that

are difficult to quantitate. The regression coefficient for all Plant E samples excluding the very strong sample of each set is a passable 0.74 with a slope of 5.82.

In conclusion, the samples from Plants A and C provide good correlation of the COU and OU data with nearly linear plots, while the other three plants give fair to good regression plots when the high-odour, amine-rich samples are excluded from calculations.

7.4 CONFIRMATION OF MNC IDENTIFICATION BY SYNTHESIS

In order to confirm that the compounds identified as MNCs are correct and account for most of the render odour, a synthetic mixture was prepared from the pure chemical standards obtained for the Odour threshold determination. The composition of the Odour from Plant C was used as a guide in the preparation. A selection of four aldehydes was mixed in a tedlar bag while a selection of four sulphur compounds was prepared in another, and a selection of four alcohols and two ketones was mixed in a third bag. Methylamine was prepared at a suitable concentration, 15 ppm, in a fourth bag. These same mixtures were then all combined in the same amounts as in the individual samples into a fifth sample bag. Another bag was prepared with only 25% of the amount of the aldehyde mixture. All of these samples were analysed by dynamic olfactometry, thermal desorbtion GC-MS and electronic nose.

The analysis of the mixture is presented in Table 5, where the expected concentration and Chemical Odour is listed in the column to the right of the actual Figures. Despite several small deviations from the expected concentrations, the mixture is within 5% of the designed concentration and Chemical Odour specification. The difference in the expected and actual Odour strength is 30%, but the striking matter to note is that the mixture smelled unmistakably of render odour, while the individual bags of aldehyde, sulphur and other compounds smell of the chemicals concerned. The characteristic tone of the render odour was recreated by the admixture of all the different chemical groups into a final mixture incorporating all of the MNCs. The further striking observation is the close approximation to a genuine render odour that this mixture achieves on the Electronic Nose. (Section 7.5) The synthetic odour (the lower chromatogram) is compared with a sample of odour from Plant C (the upper chromatogram)in Figure 1, where the main differences are due to the absence of some (unavailable) compounds such as 2-methylbutanal.

7.5 CHEMICAL ODOUR DISTRIBUTIONS AND FINGERPRINTING MNCs

A concise summary of all the data for each plant is presented in Tables 6 to 10, where both concentration and Chemical Odour calculations for both sets of data using both analytical columns is presented. The summation of all sulphur and aldehydic compounds has been described previously but it will be demonstrated how this treatment of the data enables several further observations to be made.

An examination of the Table for each plant reveals that there is a remarkable similarity in the data for the two sampling days for both Plants B, C and E (Tables 7,8 and 10). In addition the data for both polar and nonpolar columns is remarkably similar for the first two plants. The notable example was the Tallow Boiler at Plant B which was boiling away a high proportion as steam on the second occasion, requiring the sample to be diluted with air after the water had condensed. The lower values for the polar column for Plant E have been previously discussed in section 6.2.

Table 5. Anticipated and actual concentration, chemical odour and odour strength for synthetic render odour

Synthetic Odour mixture	**Odour mix 1**	**expected values**	Threshold (ppb)	**Odour mix 1**	**expected values**
20-Apr-98	**concentration**			**Chemical Odour**	
component (ppb)					
hydrogen sulphide	1,179	1,000	0.25	4,715	4000
methylmercaptan	811	1,000	0.35	2,316	2,857
dimethylsulphide	13.0	10	0.97	13.37	10
dimethyldisulphide	254	200	1.76	144	114
butanal	0.9		0.5	1.75	0.0
2-methylpropanal	679	1,000	0.54	1,257	1,852
3-methylbutanal	3,802	4,000	0.24	15,841	16,667
pentanal			5.0		
hexanal	410	200	5.9	69.46	34
heptanal	5.9	20	0.7	8.14	27
methanol	3,037	1,000	1000	3.04	1.0
ethanol	17,467	20,000	1,750	9.98	11.4
i-propanol	843	250	500	1.69	0.5
propanol	1,123	700	600	1.87	1.2
acetone	1,095	700	420	2.61	1.7
2-butanone	85	70	9.0	9.41	7.8
Sum Sulphurs	2,256	2,210	Sum Sulphurs	**7,189**	6,981
Sum Aldehydes	4,898	5,220	Sum Aldehydes	**17,178**	18,580
Sum others	23,651	22,720	Sum others	**29**	24
TOTAL ppb	**30,805**	**30,150**	**COU**	**24,395**	25,584
			OU/m^3	**33,000**	**30,000**

Table 1 Summary of Volatile Organic Compounds in Meat Processing Plant

Plant A	concentration			
6-Nov-97	Blood drier	Biofilter	Biofilter	Kill floor
nonpolar column	Outlet	outlet	inlet	air vent
Sum Sulphurs	130	119	620	40
Sum Aldehydes	510	119	652	56
Sum others	2,214	362	2,772	1,872
TOTAL (ppb)	**2,853**	**600**	**4,045**	**1,969**
6-Nov-97				
polar column	concentration			
Sum Sulphurs	58	77	289	14
Sum Aldehydes	428	110	433	33
Sum others	2,350	286	2,161	1,445
TOTAL (ppb)	**2,836**	**473**	**2,883**	**1,493**

Plant A	COU			
6-Nov-97	Blood drier	Biofilter	Biofilter	Kill floor
nonpolar column	Outlet	outlet	inlet	air vent
Sum Sulphurs	194	9	1,341	70
Sum Aldehydes	1,247	101	1,300	66
Sum others	6	2	8	2
COU	**1,447**	**113**	**2,648**	**138**
OU/m^3	**4,790**	**564**	**7,640**	**912**
ratio (OU/COU)	3.3	5.0	2.9	6.6
polar column	COU			
Sum Sulphurs	51	53	588	27
Sum Aldehydes	924	128	1,162	57
Sum others	5	1	4	1
COU	**980**	**182**	**1,754**	**85**
OU/m^3	**4,790**	**564**	**7,640**	**912**
ratio (OU/COU)	4.9	3.1	4.4	10.7

Plant A	concentration			
18-Dec-97	Cooker room	Biofilter	Biofilter	Kill floor
nonpolar column	exhaust	outlet	inlet	air vent
Sum Sulphurs	99	147	88	11
Sum Aldehydes	265	53	181	17
Sum others	884	1,675	1,985	252
TOTAL ppb	**1,248**	**1,875**	**2,254**	**279**
18-Dec-97				
polar column	concentration			
Sum Sulphurs	43	106	62	19
Sum Aldehydes	294	87	343	20
Sum others	461	294	977	166
TOTAL ppb	**798**	**487**	**1,382**	**204**

Plant A	COU			
18-Dec-97	Cooker room	Biofilter	Biofilter	Kill floor
nonpolar column	exhaust	outlet	inlet	air vent
Sum Sulphurs	230	62	10	16
Sum Aldehydes	514	67	431	18
Sum others	5	29	8	1
COU	**749**	**158**	**449**	**34**
OU/m^3	**7,530**	**8,220**	**12,100**	**452**
ratio (OU/COU)	10.1	52.0	27.0	13.1
polar column	COU			
Sum Sulphurs	79	149	50	14
Sum Aldehydes	837	111	590	38
Sum others	15	5	8	7
COU	**932**	**265**	**647**	**59**
OU/m^3	**7,530**	**8,220**	**12,100**	**452**
ratio (OU/COU)	8.1	31.0	18.7	7.7

Table ... Summary of Volatile Organic Compounds in Meat Processing Plant

Plant B	concentration				
19-Nov-97	Cooker Gas	Press Air	Blood Drier Outlet	allow Boiling Tank	DAF Tank
nonpolar column					
Sum Sulphurs	5,509	4,562	185	3,640	110
Sum Aldehydes	28,836	6,737	141	21,152	105
Sum others	14,163	19,612	687	7,437	1,348
TOTAL (ppb)	**48,508**	**30,910**	**1,014**	**32,229**	**1,563**
19-Nov-97					
polar column	concentration				
Sum Sulphurs	214	117	N/A	431	N/A
Sum Aldehydes	6,265	2,223	N/A	5,372	N/A
Sum others	3,485	1,311	N/A	2,773	N/A
TOTAL (ppb)	**9,965**	**3,650**	**N/A**	**8,576**	**N/A**

Plant B	COU				
19-Nov-97	Cooker Gas	Press Air	Blood Drier Outlet	allow Boiling Tank	DAF Tank
nonpolar column					
Sum Sulphurs	10,758	12,222	646	9,910	334
Sum Aldehydes	87,734	18,789	156	64,371	194
Sum others	100	70	3	84	4
COU	**98,593**	**31,081**	**804**	**74,364**	**532**
OU/m^3	**48,600**	**460,000**	**15,000**	**121,000**	**9,030**
ratio (OU/COU)	0.5	14.8	18.6	1.6	17.0
polar column	COU				
Sum Sulphurs	103	64	N/A	242	N/A
Sum Aldehydes	10,723	4,900	N/A	10,299	N/A
Sum others	19	32	N/A	30	N/A
COU	**10,846**	**4,996**	**N/A**	**10,570**	**N/A**
OU/m^3	**48,600**	**460,000**	**15,000**	**121,000**	**9,030**
ratio (OU/COU)	4.5	92.1		11.4	

Plant B	concentration			
19-Dec-97	Cooker Gas	Press Air	Blood Drier Outlet	Tallow Boiling Tank
nonpolar column				
Sum Sulphurs	449	2,203	1,150	715
Sum Aldehydes	4,234	22,803	449	6,029
Sum others	9,245	6,135	1,024	5,875
TOTAL ppb	**13,929**	**31,141**	**2,622**	**12,619**
19-Dec-97				
polar column	concentration			
Sum Sulphurs	822	4,470	185	4,714
Sum Aldehydes	5,024	7,369	434	3,302
Sum others	9,527	25,702	805	9,588
TOTAL ppb	**15,373**	**37,541**	**1,424**	**17,604**

Plant B	COU			
19-Dec-97	Cooker Gas	Press Air	Blood Drier Outlet	Tallow Boiling Tank
nonpolar column				
Sum Sulphurs	447	5,601	3,496	1,620
Sum Aldehydes	13,034	15,508	716	14,414
Sum others	76	44	6	59
COU	**13,557**	**21,153**	**4,217**	**16,092**
OU/m^3	**44,900**	**240,000**	**12,400**	**23,400**
ratio (OU/COU)	3.3	11.3	2.9	1.5
polar column	COU			
Sum Sulphurs	1,261	12,410	552	12,816
Sum Aldehydes	4,782	10,367	179	8,379
Sum others	21	49	2	32
COU	**6,064**	**22,826**	**733**	**21,227**
OU/m^3	**44,900**	**240,000**	**12,400**	**23,400**
ratio (OU/COU)	7.4	10.5	16.9	1.1

Table C Summary of Volatile Organic Compounds in Meat Processing Plant

Plant C	concentration				
26-Nov-97	RP 2	Scrubber	RP 3	Scrubber	
nonpolar column		Outlet		Inlet	
Sum Sulphurs	206	5,799	252	5,392	
Sum Aldehydes	160	4,742	38	5,829	
Sum others	813	16,470	1,027	16,846	
TOTAL (ppb)	**1,179**	**27,012**	**1,317**	**28,067**	
26-Nov-97					
polar column	concentration				
Sum Sulphurs	82	4,470	185	4,714	
Sum Aldehydes	136	5,715	68	6,919	
Sum others	953	25,702	805	9,588	
TOTAL (ppb)	**1,171**	**35,887**	**1,058**	**21,220**	

Plant C	COU				
26-Nov-97	RP 2	Scrubber	RP 3	Scrubber	
nonpolar column		Outlet		Inlet	
Sum Sulphurs	528	15,946	733	14,339	
Sum Aldehydes	464	14,807	53	15,529	
Sum others	4	65	3	67	
COU	**997**	**30,818**	**788**	**29,935**	
OU/m^3	**8,960**	**203,000**	**7,960**	**161,000**	
ratio (OU/COU)	9.0	6.6	10.1	5.4	
polar column	COU				
Sum Sulphurs	126	12,410	552	12,817	
Sum Aldehydes	356	9,816	57	9,584	
Sum others	2	49	2	32	
COU	**484**	**22,275**	**611**	**22,433**	
OU/m^3	**8,960**	**203,000**	**7,960**	**161,000**	
ratio (OU/COU)	18.5	9.1	13.0	7.2	

Plant C	concentration				
4-Mar-98	RP 3	Scrubber	RP 3	Scrubber	RP 1
nonpolar column	before ozone	Outlet	after ozone	Inlet	stack
Sum Sulphurs	124	7,458	46	20,075	2,020
Sum Aldehydes	10	2,525	11	2,761	181
Sum others	525	8,326	585	10,054	1,021
TOTAL ppb	**659**	**18,309**	**642**	**32,891**	**3,223**
4-Mar-98					
polar column	concentration				
Sum Sulphurs	N/A	N/A	N/A	N/A	N/A
Sum Aldehydes	N/A	N/A	N/A	N/A	N/A
Sum others	N/A	N/A	N/A	N/A	N/A
TOTAL ppb	N/A	N/A	N/A	N/A	N/A

Plant C	COU				
4-Mar-98	RP 3	Scrubber	RP 3	Scrubber	RP 1
nonpolar column	before ozone	Outlet	after ozone	Inlet	stack
Sum Sulphurs	364	25,807	120	68,797	223
Sum Aldehydes	11	8,977	9	8,995	521
Sum others	1	30	1	43	3
COU	**375**	**34,814**	**130**	**77,834**	**747**
OU/m^3	**21,930**	**200,000**	**15,680**	**335,000**	**13,400**
ratio (OU/COU)	58.5	5.7	121	4.3	17.9
polar column					
Sum Sulphurs	N/A	N/A	N/A	N/A	N/A
Sum Aldehydes	N/A	N/A	N/A	N/A	N/A
Sum others	N/A	N/A	N/A	N/A	N/A
COU	N/A	N/A	N/A	N/A	N/A
OU/m^3	N/A	N/A	N/A	N/A	N/A
ratio (OU/COU)	N/A	N/A	N/A	N/A	N/A

Table ... Summary of Volatile Organic Compounds in Meat Processing Plant

Plant D	concentration						COU					
15-Nov-97	Fish pile	Waste water	Hammermill	Tallow Day			Fish pile	Waste water	Hammermill	Tallow Day		
nonpolar column		Shaker screen	room	Tank				Shaker screen	room	Tank		
Sum Sulphurs	373	951	754	257			1,013	2,735	2,493	760		
Sum Aldehydes	118	108	268	455			244	225	780	1,330		
Sum others	3,490	7,345	1,348	1,171			8	11	5	4		
TOTAL (ppb)	**3,981**	**8,404**	**2,370**	**1,884**			**COU**	**1,266**	**2,971**	**3,277**	**2,094**	
							OU/m^3	**5,070**	**15,600**	**1,190**	**3,560**	
							ratio (OU/COU)	4.0	5.3	0.4	1.7	
	concentration											
15-Nov-97	Biofilter	Biofilter	BNR plant	Red Meat	Blood Tank	Incinerator	15-Nov-97	Biofilter	Biofilter	BNR plant	Red Meat	Blood Tank	Incinerator
nonpolar column	inlet	outlet		receival			nonpolar column	inlet	outlet		receival		
Sum Sulphurs	777	133	1,656	531	155,120	645,043	Sum Sulphurs	1,851	105	4,572	1,709	542,694	1,907,081
Sum Aldehydes	1,195	29	111	47	2,389	551,788	Sum Aldehydes	3,595	38	228	70	1,224	1,705,444
Sum others	1,377	386	3,311	1,025	17,797	340,752	Sum others	6	4	11	2	25	1,026
TOTAL (ppb)	**3,349**	**549**	**5,078**	**1,603**	**175,306**	**1,537,583**	**COU**	**5,452**	**146**	**4,810**	**1,782**	**543,943**	**3,613,551**
							OU/m^3	**7,150**	**930**	**3,360**	**5,650**	**602,000**	**275,000**
							ratio (OU/COU)	1.3	6.4	0.7	3.2	1.1	0.1
Plant D	concentration						**Plant D**	COU					
23-Jan-98	Biofilter	Biofilter	BNR plant	Red Meat	Blood	Incinerator	23-Jan-98	Biofilter	Biofilter	BNR plant	Red Meat	Blood	Incinerator
nonpolar column	inlet	outlet		cooker	cooker		nonpolar column	inlet	outlet		cooker	cooker	
Sum Sulphurs	4,208	885	143	1,223	5,928	704,819	Sum Sulphurs	12,150	2,112	450	3,439	17,270	2,521,595
Sum Aldehydes	922	41	83	480	271	220,565	Sum Aldehydes	2,542	42	62	970	294	688,377
Sum others	10,117	1,147	1,194	2,764	13,036	78,972	Sum others	30	2	2	6	16	473
TOTAL ppb	**15,247**	**2,073**	**1,421**	**4,468**	**19,235**	**1,004,356**	**COU**	**14,722**	**2,156**	**514**	**4,415**	**17,579**	**3,210,446**
							OU/m^3	**22,900**	**9,690**	**376**	**756**	**17,500**	**340,000**
23-Jan-98							ratio (OU/COU)	1.6	4.5	0.7	0.2	1.0	0.1
polar column	concentration						polar column	COU					
Sum Sulphurs	1,052	454	34	905	37,716	94,111	Sum Sulphurs	2,968	1,187	85	2,993	111,859	289,856
Sum Aldehydes	618	35	57	293	1,925	80,526	Sum Aldehydes	762	26	70	853	2,301	251,990
Sum others	4,120	487	627	1,259	79,985	24,963	Sum others	4	0	1	2	57	80
TOTAL ppb	**5,790**	**975**	**718**	**2,456**	**119,626**	**199,600**	**COU**	**3,734**	**1,213**	**156**	**3,848**	**114,217**	**541,927**
							OU/m^3	**22,900**	**9,690**	**376**	**756**	**17,500**	**340,000**
							ratio (OU/COU)	6.1	8.0	2.4	0.2	0.2	0.6

Table 6. Summary of Volatile Organic Compounds in Meat Processing Plant

Plant E	concentration					
17-Oct-97	Drier (in)	Non	Factory air	Drier (out)	Raw	
nonpolar column		condensibles			materials	
Sum Sulphurs	699	55,783	734	609	139	
Sum Aldehydes	2,789	10,302	1,090	678	61	
Sum others	7,767	5,891	1,580	2,191	893	
TOTAL (ppb)	**11,254**	**71,977**	**3,403**	**3,478**	**1,092**	
17-Oct-97						
polar column	concentration					
Sum Sulphurs	223	16,026	264	114	67	
Sum Aldehydes	1,588	3,230	817	288	76	
Sum others	7,339	3,938	787	537	539	
TOTAL (ppb)	**9,150**	**23,194**	**1,868**	**938**	**681**	

Plant E	COU					
17-Oct-97	Drier (in)	Non	Factory air	Drier (out)	Raw	
nonpolar column		condensibles			materials	
Sum Sulphurs	414	162,640	1,925	230	379	
Sum Aldehydes	4,135	31,532	3,155	803	83	
Sum others	146	48	11	167	4	
COU	**4,695**	**194,220**	**5,091**	**1,200**	**467**	
OU/m^3	**37,000**	**220,000**	**21,600**	**19,100**	**2,050**	
ratio (OU/COU)	7.9	1.1	4.2	15.9	4.4	
polar column	COU					
Sum Sulphurs	119	52,352	695	32	218	
Sum Aldehydes	2,388	9,677	2,152	359	102	
Sum others	24	24	4	5	1	
COU	**2,532**	**62,052**	**2,850**	**397**	**321**	
OU/m^3	**37,000**	**220,000**	**21,600**	**19,100**	**2,050**	
ratio (OU/COU)	14.6	3.5	7.6	48.2	6.4	

Plant E	concentration						
10-Nov-97	Drier (in)	Non	Factory air	Drier (out)	Raw	Cookers	
nonpolar column		condensibles			materials	insp. gantry	
Sum Sulphurs	3,239	149,325	472	84	267	418	
Sum Aldehydes	726	18,432	525	42	121	128	
Sum others	6,776	6,751	2,015	592	399	532	
TOTAL ppb	**10,741**	**174,508**	**3,012**	**719**	**787**	**1,078**	
10-Nov-97							
polar column	concentration						
Sum Sulphurs	391	50,606	257	22	129	343	
Sum Aldehydes	161	10,478	219	49	44	164	
Sum others	4,012	3,227	1,129	238	185	338	
TOTAL ppb	**4,565**	**64,311**	**1,605**	**310**	**358**	**846**	

Plant E	COU					
10-Nov-97	Drier (in)	Non	Factory air	Drier (out)	Raw	Cookers
nonpolar column		condensibles			materials	insp. gantry
Sum Sulphurs	830	530,414	733	78	940	1,466
Sum Aldehydes	1,344	65,494	1,440	75	192	335
Sum others	57	27	10	5	3	3
COU	**2,231**	**595,935**	**2,182**	**159**	**1,134**	**1,804**
OU/m^3	**30,900**	**8,700,000**	**10,600**	**508**	**756**	**10,700**
ratio (OU/COU)	13.8	14.6	4.9	3.2	0.7	5.9
polar column	COU					
Sum Sulphurs	847	171,784	456	57	465	1,176
Sum Aldehydes	98	34,349	498	43	62	394
Sum others	4	8	3	0	0	1
COU	**949**	**206,141**	**956**	**100**	**527**	**1,570**
OU/m^3	**30,900**	**8,700,000**	**10,600**	**508**	**756**	**10,700**
ratio (OU/COU)	32.6	42.2	11.1	5.1	1.4	6.8

Table ... Summary of Volatile Organic Compounds in Meat Processing Plant

Plant C	RP 2	Scrubber	RP 3	Scrubber
26-Nov-97		Outlet		Inlet
nonpolar column	concentration			
Sum Sulphurs	206	5,799	252	5,392
Sum Aldehydes	160	4,742	38	5,829
Sum others	813	16,470	1,027	16,846
TOTAL (ppb)	**1,179**	**27,012**	**1,317**	**28,067**
26-Nov-97				
polar column	concentration			
Sum Sulphurs	82	4,470	185	4,714
Sum Aldehydes	136	5,715	68	6,919
Sum others	953	25,702	805	9,588
TOTAL (ppb)	**1,171**	**35,887**	**1,058**	**21,220**

Plant C	RP 2	Scrubber	RP 3	Scrubber
26-Nov-97		Outlet		Inlet
nonpolar column	COU			
Sum Sulphurs	528	15,946	733	14,339
Sum Aldehydes	464	14,807	53	15,529
Sum others	4	65	3	67
COU	**997**	**30,818**	**788**	**29,935**
OU/m^3	**8,960**	**203,000**	**7,960**	**161,000**
ratio (OU/COU)	9.0	6.6	10.1	5.4
polar column				
Sum Sulphurs	126	12,410	552	12,817
Sum Aldehydes	356	9,816	57	9,584
Sum others	2	49	2	32
COU	**484**	**22,275**	**611**	**22,433**
OU/m^3	**8,960**	**203,000**	**7,960**	**161,000**
ratio (OU/COU)	18.5	9.1	13.0	7.2

Plant A	Blood drier	Biofilter	Biofilter	Kill floor
6-Nov-97	Outlet	outlet	inlet	air vent
nonpolar column	concentration			
Sum Sulphurs	130	119	620	40
Sum Aldehydes	510	119	652	56
Sum others	2,214	362	2,772	1,872
TOTAL (ppb)	**2,853**	**600**	**4,045**	**1,969**
6-Nov-97				
polar column	concentration			
Sum Sulphurs	58	77	289	14
Sum Aldehydes	428	110	433	33
Sum others	2,350	286	2,161	1,445
TOTAL (ppb)	2,836	473	2,883	1,493

Plant A	Blood drier	Biofilter	Biofilter	Kill floor
6-Nov-97	Outlet	outlet	inlet	air vent
nonpolar column	COU			
Sum Sulphurs	194	9	1,341	70
Sum Aldehydes	1,247	101	1,300	66
Sum others	6	2	8	2
COU	**1,447**	**113**	**2,648**	**138**
OU/m^3	**4,790**	**564**	**7,640**	**912**
ratio (OU/COU)	3.3	5.0	3	6.6
polar column				
Sum Sulphurs	51	53	588	27
Sum Aldehydes	924	128	1,162	57
Sum others	5	1	4	1
COU	**980**	**182**	**1,754**	**85**
OU/m^3	**4,790**	**564**	**7,640**	**912**
ratio (OU/COU)	5	3	4	11

In the case of Plant D (Table 9) there is obvious similarity between the two sets of data for the Incinerator and Biofilter (inlet) samples, but not the Biofilter (outlet) or BNR plant samples, though the OU/COU ratios are very similar. This is clearly the result of changed operating conditions for the ancilliary equipment involved such as the BNR and biofilter etc. Finally plant A (Table 6) shows more significant variation between the two sets of data for all the samples, in spite of the similarity between the data for the two analytical columns. An explanation may be found in that the levels of odour in this plant are the lowest overall. Consequently, small variations may produce large relative differences between the samples.

In general then it is found that data for particular plants on different days is quite similar, in some cases sources are reproducible, for others distinct changes are apparent. This is not a trivial finding and one quite difficult to make without the use of simplification in the expression of the data. It may have implications for operating practices at rendering plants.

An example of combining data for two different plants is presented in Table 11 where a specialty renderer (plant C) is compared with an integrated abattoir (plant A). The most obvious difference is the observation that the proportion of sulphur compounds in the renderer is much higher across the sample set than for the integrated sheep facility. The higher proportion of aged material is thought to account for this.

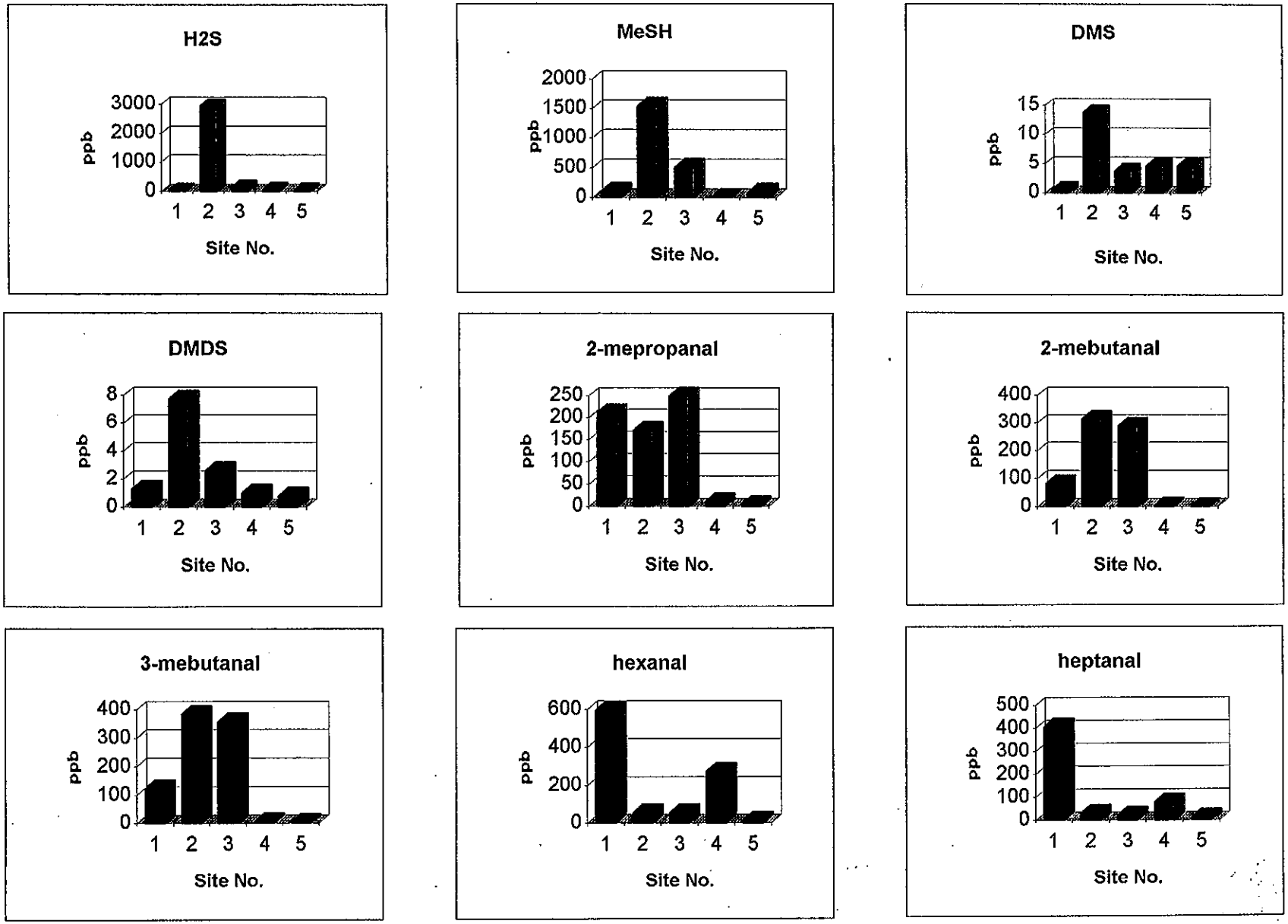
An attempt to determine which part of a plant contributes most to the total odour, in terms of individual MNCs is presented in Figure 3 for Plant E. While it is easy to see that the strongest odour source (non-condensables) contributes the great majority (>97%) of all sulphur compounds and most of the aldehydic compounds apart from hexanal and heptanal, it is difficult to see the proportion of sulphur and aldehydes contributing to each source. A simpler presentation is provided in Figures 4 to 14 which takes the sulphur and aldehyde sums from Tables 5 to 9 and presents them in pie charts (Figures 5 to 14 are contained in Appendix 3).

Considering firstly the specialist renderer, Plant D 23rd Jan, (Fig 12) there is an obvious excess of sulphur compounds with the proportion of aldehydes only ranging from 2-22%. The situation for the other data for Plant D (15th Nov, Figs 10 and 11) is similar with a slightly higher proportion of aldehydes, but the sulphur compounds are still clearly in excess. Only the Tallow tank and inlet to biofilter (Fig 10) having an excess of aldehydes (66%).

By comparison the Tallow tank at the integrated beef abattoir, Plant B (19th Nov, Fig 6) is 87% aldehydes (90% in Fig 7), while the other major odour sources, cooker gas and press air, are both substantially comprised of aldehydes. There is quite clearly a predominance of aldehydes in the odours from this abattoir. The sheep abattoir ,Plant A, (Figs 4 and 5) has a similar excess of aldehydes.

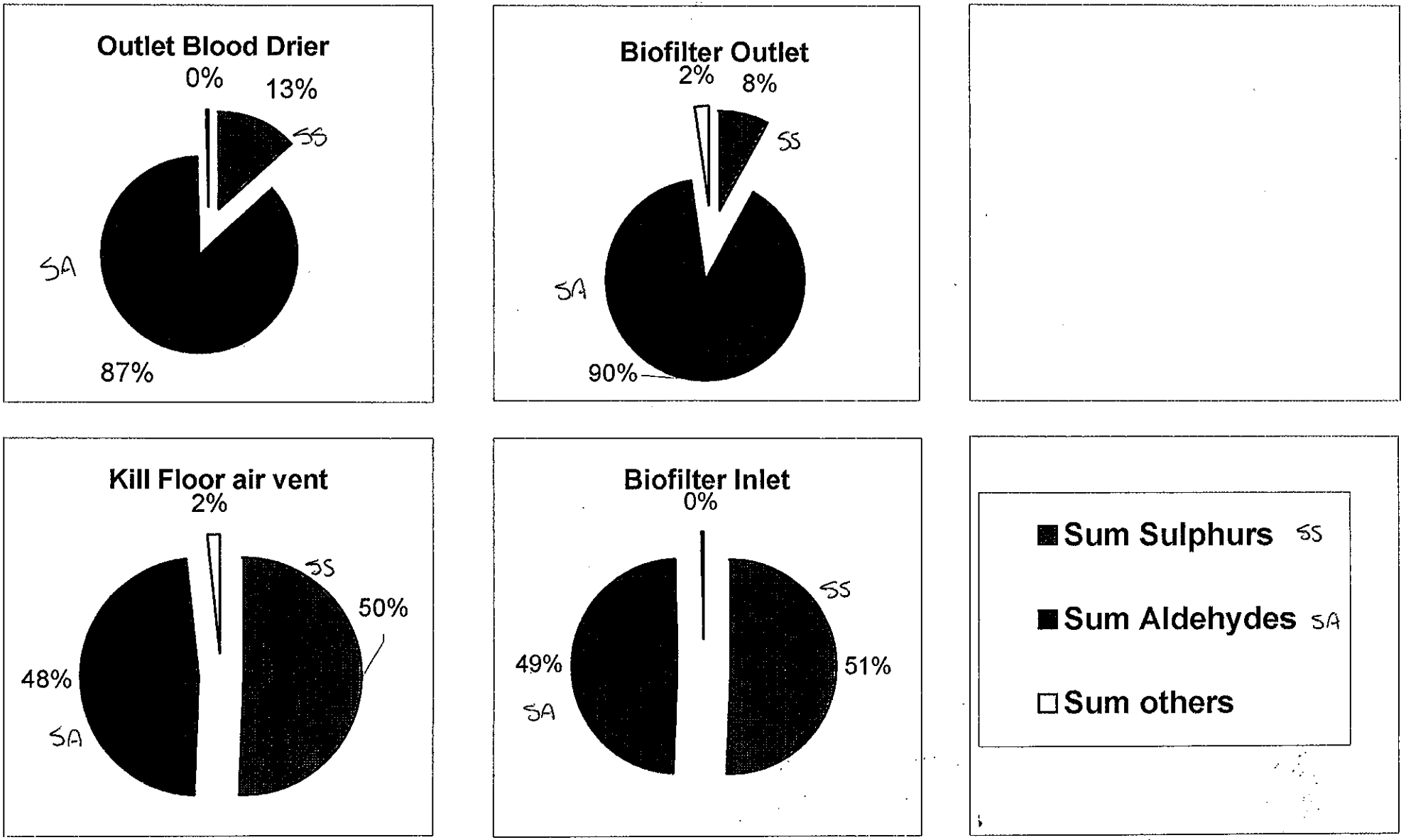
Returning to the other specialty renderers, they also show a clear excess of sulphur compounds (Plant C, Fig 9 and Plant E, Fig 14) which supports the finding that specialty renderers have higher levels of annoying sulphur compounds. Clearly the proportion of aged versus fresh offal being processed at a plant determines the proportion of sulphur and aldehyde compounds in the odour.

Figure 3. Most Nuisance Compounds from samples at Plant E, 17 Oct, 1997



KEY: SITE NO. 1 = Drier Biofilter (in)
SITE NO. 2 = Noncondensibles Biofilter
SITE NO. 3 = Factory air biofilter
SITE NO. 4 = Drier Biofilter (out)
SITE NO. 5 = Raw materials
NOTE: site 2 values divided by 10

Figure 4. Chemical Odour Distribution for Plant A, 6 Nov,1997



7.6 CORRELATION OF ELECTRONIC NOSE DATA WITH OLFACTOMETRY AND CHEMICAL ANALYSIS

A discussion of the operating principles and methodology employed in the collection of Electronic Nose data is presented in appendix 5, a specialist report prepared by AFISC. A series of principal component maps are used to display the results for the 19 render samples analysed using the Aromascanner (maps 1,3,5,7) and the Fox 4000 (maps 2,4,6,8). The regression coefficients for correlation of Aromascanner data (principle components 1 and 2; PC1, PC2), Olfactometric data (OU) and chemical analysis data (Total Chemical Odour, COU and the sums of sulphur and aldehyde compounds) are displayed in Table 12. There are clearly a number of excellent correlations, in particular plant C which demonstrates good correlation between all three techniques, and several plants where 2 of the three techniques correlate well. Notably, none of the plants are without a reasonable correlation for at least 2 methods of analysis.

Table 12: Comparisons of Correlations for Aromascan (pc1or pc2) and Olfactometry vs Chemical Analysis and Olfactometry.

Plant/ parameter	Odour (OU)	Chemical Odour (COU)	Sum Sulphurs	Sum Aldehyde
Plant C/ PC1	0.93	0.88	0.85	0.99
Plant C/ OU	---	0.99	0.98	0.94
Plant D/ PC1	0.65	0.90	0.90	0.90
Plant D/ OU	---	0.79	0.79	0.79
Plant A/ PC1	0.93	0.42	0.15	0.44
Plant A/ PC2	0.37	0.97	0.89	0.65
Plant A/ OU	---	0.55	---	0.65
Plant B/ PC1	0.61	0.95	---	0.98
Plant B/ OU	---	0.75	0.76	0.52

In addition the Aromascanner was used to demonstrate the concentration sensitivity of the E-Nose for samples from the same source by analysing a series of dilutions of a moderate strength sample (CHOS 8319) from plant C shown in map 9. Finally, the Aromascanner was used to compare a series of pure odorants and chemical mixtures used to prepare the synthetic odour mixture, data shown in map 10.
The samples were:

- CHOS 8410 methylmercaptan, 0.5 ppm;
- CHOS 8411 final mix normal aldehyde; (concentrations in samples 8413, 8422, 8423);
- CHOS 8412 final mix low aldehyde; (25% the normal aldehyde concentration, sample 8411);
- CHOS 8413 solvents mix; ethanol 40 ppm, methanol 1ppm, i-propanol 0.25ppm, propanol 0.7ppm, acetone 0.7ppm, 2-butanone 0.07ppm;

- CHOS 8414 methylamine, 15ppm;
- CHOS 8415 hexaldehyde, 5 ppm;
- CHOS 8418 dimethyl disulphide, 5 ppm;
- CHOS 8420 2-methylpropanal, 5 ppm;
- CHOS 8421 3-methylbutanal, 5 ppm;
- CHOS 8422 sulphur mix; H2S 1ppm, MeSH 1ppm, DMDS 0.1ppm, DMS 0.01ppm; and
- CHOS 8423 aldehyde mix; 3-methylbutanal 4ppm, 2-methylpropanal 1ppm, hexanal 0.1ppm, heptanal 0.025ppm.

An examination of map 10 shows that the aldehyde and sulphide mixtures map close to a geometric centre of the respective individual components of each, while the solvents and amine are overlapping the sulphur mixture but not the aldehyde mixture. The aldehyde mixtures (8423, 8412, and 8411) appear to be discriminated with strength of odour in the x axis, and the complete synthetic render mixtures (CHOS 8423, 8412 and 8411) map progressively further away from the individual (aldehyde-, sulphur- and solvent) mixtures with closer resemblance to the actual concentrations in render odour. When the synthetic render mixtures and the aldehyde mixture are mapped with the samples from plant C (upon which concentration of sample CHOS 8319 the synthetic mix were designed to emulate) they plot in the lower concentration side of the map and are sequentially in the correct order for increasing concentration from left to right. Thus there is a remarkable progressively closer approach of the sensor responses of the synthetic with that of the genuine as the components of the synthetic approach the correct concentrations, (map 11).

Alexander comments (appendix 5, p18) on apparent inconsistencies in map 12, suggesting that this may result from the fact that some of the data for the E-Nose were collected from samples over 1 month old. Those samples affected by the long time delay were the second sets from plants A and plant B (CHOS 613-620). The second sets from plant C (CHOS 8319-23) and plant D (CHOS 707-712) were analysed within one week of collection. No samples from Plant E were collected in time for E-Nose analysis. Rather than appear inconsistent, map 12 clearly indicates that the synthetic samples map very closely with the moderate strength samples from Plant C as expected, while the samples next nearest are the weak odours from plants B, D and all the (weak) odours from plant A. The samples further removed are the strong odour samples from plants C and B, while the strong sample from plant D is quite distant showing distinct differences in the other principal component. This map quite clearly shows that all render odours are distinct but close in vector space to each other as might be reasonably expected by the relatively small differences in the hedonic tone of samples between different plants.

8 CONCLUSIONS

This project commenced with a relatively well defined scope of work and a clear set of objectives, yet evolved into a more complex evaluation of meat industry odours, including sources, characteristics, three methods of measurement and correlations between all three methods. Before drawing together the principal conclusions of the work it is worth summarising the most significant findings of the project, in order to place the conclusions and subsequent recommendations in the correct context. These findings are as follows:

- Olfactometry will continue to have a role as the most practical and relevant technique for odour auditing and process optimisation applications in meat processing plants. The technique is able to clearly quantify the odour emissions from individual sources as well as the plant as a whole, and will remain the preferred method for evaluating odour control system performance for some years to come. It is still the preferred odour assessment method by environmental regulators around Australia;

- Chemical analysis of meat industry odours, using sophisticated GC-MS technology will also continue to be used in source measurement applications but to a decreasing extent as alternative techniques become available. This project has identified a possible successor in the SPME GC-MS method, but more work is required to confirm its usefulness in meat industry odour applications;

- The project found excellent correlations between the olfactometry and GC-MS results for three of the five plants (plants A, C & D) and good correlations for the remaining two plants (B & E). The inference from these results is that excellent correlations indicate that all Most Nuisance Compounds were identified and quantified by the COU model for plants A, C & D, while an additonal odour compound group may have contributed to the odours from plants B & E, thus affecting the correlation. The project concluded that amines are most likely to be the chemical group involved, because they are not easily quantified using the GC-MS methods employed in this study; and

- The Most Nuisance Compounds for the odour emissions from the five plants studied by the project were identified, with a high degree of confidence. The simple chemical odour unit (COU) model developed by the team identified that the bulk of the odour emitted by the plants was composed of the following compounds, the concentrations and significance of which depended on individual processing operations.

Compound	Chemical Group
Hydrogen sulphide dimethyl sulphide dimethyl disulphide methyl mercaptan	Reduced Sulphur Compounds
3-methyl butanal 2-methyl butanal 2-methyl propanal heptanal	Aldehydes

- The project team found it more practical to use the two chemical groups to identify differences in sources within plants and between plants rather than considering the individual compounds themselves, because of large variations in concentrations of individual compounds;

- Ketone compounds were also identified in significant quantities but the relatively high threshold concentrations of the ketones resulted in this group having a relatively minor impact on the overall level of odour;

- The relative contribution of the reduced sulphur and aldehyde compounds to perceived odour levels varied from plant to plant, with a general tendency for plants receiving older raw materials having higher and more significant levels of sulphur compounds in their odorous emissions. This finding is not surprising, given that little effort is given to maintaining raw material in a fresh condition during transportion to rendering plants;

- The project team was able to successfully synthesise meat processing and rendering odours, using a mixture of the MNCs identified during the project. The result, in itself, validated the COU hypothesis used by the team to identify MNC compounds; and

- The e-nose technology used in the project had limited success in discriminating between the pure MNC compounds but was able to differentiate between different odour samples from the five plants studied. The e-nose technology also appears to be able to differentiate between different concentrations of the same odour. The e-nose and olfactory assessments by team members could not easily distinguish between a synthetic odour sample and the 'real' sample upon which the synthetic sample was based. This result indicates that the e-nose device does behave somewhat like a human nose and confirms the potential for this technology.

Table 13 draws together the principal olfactometry and chemical results of the project in a form which may assist the meat industry better understand the nature and range of odour emissions which can arise in abattoirs and rendering plants in Australia. In the preparation of Table 13 a small number of extreme values have been excluded, on the understanding that each may have resulted from a processing event which was not representative of the industry as a whole.

- That a simpler and cheaper gas chromatographic (GC) method is likely to be successful with meat industry odours where the characterisation of moderately strong samples is required. The SPME method was successful in this role, although further developmental work is required before the method could be used to assess odour strength/concentration, particularly for weaker samples;

- That e-nose technology, in its present stage of development, shows considerable promise as an alternative to olfactomertry and GC-MS analysis methods. The technology is developing rapidly and instrument performance is expected to rise and prices fall in the near future. The identification by the project team of a small number of MNC compounds suggests that smaller, less complex and cheaper e-nose instruments could be developed specifically for meat industry applications. Australia has several research groups active in the area of applied research which could assist in the task; and

- Olfactometry will continue to be required for odour impact assessment, odour audits, the design of odour reduction systems and other applications where an actual perceived odour concentration is required.

9 RECOMMENDATIONS

The results of the project, when interpreted in the context of the prescribed scope of work, have achieved the objectives of identifying the main compounds responsible for meat industry odours and developing or identifying a more practical and cost effective means of measuring such odours.

The project has identified the potential of e-nose technology for the industry in both source and ambient odour measurement and discrimination applications. It has also successfully trialled a simpler GC method more applicable to source measurement and discrimination.

As a result of this study the following recommendations are made, as a means of progressing and adding value to the findings of this project. The recommendations represent the parallel development of two different but practical alternatives to olfactometry and GC-MS . They are not listed in any priority order:

Recommendation 1:

"That the 'second generation' of e-nose technology be evaluated by the meat industry with the view to this technology being routinely used to assess compliance with 'no nuisance' odour standards and possibly to assess the performance of odour control systems".

Two approaches to this are possible and each is supported by the project team:

- An on-going assessment of commercial e-nose instruments as they come onto the market. The instrument sector is extremely competitive and to a large extent, marketing by suppliers will encourage the meat industry to critically evaluate each new product. Caution is needed in order to prevent multiple and differing instrument technologies from being used in the industry. Such confusion has existed in the olfactometry field, prior to the new draft Australian Standard Method; and

- The development of a meat industry – specific e-nose instrument, specifically designed to detect the MNCs identified by this project. It is envisaged that such an instrument might be far less complex than the 20 sensor (typically) commercial e-nose instruments used in this project. Preliminary discussions with Australian Research and Development groups with expertise in this area has indicated that a three or four sensor instrument is feasible, using freely available, current generation sensors. Sensor development and the commercial potential for such an instrument should ensure that any prototype instrument will continue to be developed, without meat industry resources beyond an initial investment. A prototype instrument could be developed within one year.

Recommendation 2:

"That the alternative SPME gas chromatography method be trialled at two rural-based chemical laboratories, with the view to establishing the value and practicability of this technique as an alternative to GC-MS analysis."

10 CONSEQUENCES OF THE RECOMMENDATIONS

This project has recommended two actions which, if implemented, will determine whether the Australian meat industry will need to continue to rely on dynamic olfactometry and GC-MS odour measurement methods in the future.

An alternative GC method is proposed, which if found in the trial to be viable and effective, will provide the industry with a simpler and less costly means of identifying and possibly quantifying source odour samples. The project has identified key MNCs upon which the method will focus, with little need for the assessment of other compounds in meat industry odours. It is envisaged that local/regional laboratories will be able to provide the testing service.

The development of an industry specific electronic nose instrument now appears to be viable, particularly now that the MNCs have been identified and are relatively few in number. The availability of such an instrument, at a cost affordable by individual processing plants, would provide environmental managers with a monitoring tool which could be used in 'real time' assessment of odours at the source and perhaps even at receptor locations. Such a scenario would have been unheard of several years ago but now appears to be a realistic and achievable objective for the industry.

11 IMPLEMENTATION PLAN

The following implementation plan for progressing the recommendations of this project:

1) The distribution of this report or its executive summary within the meat industry, possibly complemented with explanatory seminars presented by the authors,

2) Discussions between the Meat and Livestock Association and qualified and experienced R & D groups aimed at developing a proposal and delivery pathway for a meat industry e-nose instrument, and

Establishment of a specialist team to watch over the development in commercial e-nose technology, particularly devices designed for applications in industries known to have odours influenced by aldehydes and reduced sulphur compounds.

APPENDIX 1

OLFACTOMETRY RESULTS

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 24 November 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant A

SAMPLE COLLECTION DATE: 6 November, 1997

SAMPLE TESTING DATE: 7 November, 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m³)
Blood Dryer Outlet	543	4,790
Biofilter Outlet	544	564
Biofilter Inlet	545	7,640
Kill Floor Air Vent	546	912
Butanol reference gas	ref1997107	530 (94 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 19 December 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant A

SAMPLE COLLECTION DATE: 17 December, 1997

SAMPLE TESTING DATE: 18 December, 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m^3)
Biofilter Outlet	613	8,220
Biofilter Inlet	614	12,100
Cooker Room Exhaust	615	7,530
Kill Floor Air Vent	616	452
Butanol reference gas	ref19971218	1,125 (44 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 24 November 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant B

SAMPLE COLLECTION DATE: 19 November 1997

SAMPLE TESTING DATE: 20 December 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m³)
Cooker Gas	574	48,600
Press Air	575	460,000
Blood Dryer Outlet	576	15,000
DAF Tank	577	9,030
Tallow Boiling Tank	578	121,000
Butanol reference gas	ref19971121am	966 (52 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 23 December 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant B

SAMPLE COLLECTION DATE: 18 December 1997

SAMPLE TESTING DATE: 19 December 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m³)
Cooker Gas	617	44,900
Press Air	618	240,000
Blood Dryer Outlet	619	12,400
Tallow Boiling Tank	620	23,400
Land Application of Effluent	621	1,870
Butanol reference gas	ref19971219	957 (52 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 27 November 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant C

SAMPLE COLLECTION DATE: 25 November 1997

SAMPLE TESTING DATE: 28 November 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m^3)
Ventilation Duct 2	590	8,960
Scrubber Outlet	591	203,000
Ventilation Duct 3	592	7,960
Scrubber Inlet	593	161,000
Butanol reference gas	ref19981126	846 (59 ppb)

Comments: Nil.

T. Schulz
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CH2M HILL ODOUR SERVICES

LABORATORY RESULTS

CLIENT: MRC **DATE:** 6 March 1998

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant C

SAMPLE COLLECTION DATE: 4 March, 1998

SAMPLE TESTING DATE: 5/6/7 March, 1998

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m^3)
Ventilation Duct 3 - Ozone	8319	21,900
Scrubber Outlet	8320	371,000
Ventilation Duct 3 Downstream	8321	15,700
Process Air Duct 1	8322	13,400
Scrubber Inlet	8323	335,000
Butanol reference gas	ref19980305pm	950 (53 ppb)

Comments: Nil.

T. Schulz
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CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 24 November 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:**101039

SAMPLE LOCATION: Plant D

SAMPLE COLLECTION DATE: 22 January 1998

SAMPLE TESTING DATE: 12 & 13 November 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m^3)
Blood Tank	553	602,000
Wastewater Shaker Screen	554	15,600
Incinerator # 1 Inlet	555	275,000
Hammermill Room	556	1,190
Tallow Day Tank	557	3,560
Wastewater Plant	558	3,360
Biofilter Inlet	559	7,150
Red Meat Receival Area	560	5,650
Biofilter Outlet	561	930
Fish Pile	562	5,070
Butanol reference gas	ref19971117	631 (79 ppb)
Butanol reference gas	ref19971117pm	1410 (35 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 23 January 1998

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:**101039

SAMPLE LOCATION: Plant D

SAMPLE COLLECTION DATE: 22 January 1998

SAMPLE TESTING DATE: 23 January 1998

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m^3)
Biofilter Inlet	707	22,900
Biofilter Outlet	708	9,690
Wastewater Plant Inlet	709	376
Red Meat Cooker Room	710	756
Blood Co-agulator	711	1,750
Incinerator Inlet	712	>34,000
Biofilter Inlet	713	> 53,700
Butanol reference gas	ref19980123-2	840 (60 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 20 October 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant E

SAMPLE COLLECTION DATE: 16 October 1997

SAMPLE TESTING DATE: 17 October 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m³)
Inlet to dryer biofilter	522	37,000
Inlet to non condensable gas biofilter	523	220,000
Inlet to factory air biofilter	524	21,600
Outlet to dryer biofilter	525	19,100
Factory air in raw materials building	526	2,050
Butanol reference gas	ref1997101?	753 (66 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

CH2MHILL

CH2M HILL ODOUR SERVICES
LABORATORY RESULTS

CLIENT: MRC **DATE:** 24 November 1997

CLIENT CONTACT: Violeta Espinas **CHOS JOB #:** 101039

SAMPLE LOCATION: Plant E

SAMPLE COLLECTION DATE: 10 November 1997

SAMPLE TESTING DATE: 11 November 1997

SAMPLING LOCATION	CHOS SAMPLE NUMBER	ODOUR CONCENTRATION (OU/m^3)
Inlet to dryer biofilter	548	30,900
Inlet to non condensable gas biofilter	551	8,700,000
Inlet to factory air biofilter	549	10,600
Outlet to dryer biofilter	550	508
Factory air in raw materials building	547	756
Inspection gantry above cookers	552	10,700
Butanol reference gas	ref19971111	842 (59 ppb)

Comments: Nil.

T. Schulz
Manager, Odour Services

APPENDIX 2

CONCENTRATIONS OF COMPOUNDS IDENTIFIED BY GC-MS

Volatile Organic components from Meat Processing Plant

Plant A	Blood drier	Biofilter	Biofilter	Kill floor
nonpolar column	Outlet	outlet	inlet	air vent
6-Nov-97				
component (ppb)		Concentration		
hydrogen sulphide	<0.1	<0.1	<0.1	<0.1
carbonylsulphide	29.1	84.9	80.8	8.9
sulphurdioxide	<0.1	<0.1	<0.1	<0.1
methylmercaptan	58.7	1.5	455	23.6
dimethylsulphide	15.1	1.1	11.6	0.2
carbondisulphide	8.8	28.4	22.5	4.7
ethylmercaptan	<0.1	<0.1	<0.1	0.3
i-propylmercaptan	<0.1	<0.1	<0.1	<0.1
propylmercaptan	<0.1	<0.1	<0.1	<0.1
dimethyldisulphide	17.5	2.2	34.8	1.5
dimethyltrisulphide	0.5	0.5	15.5	1.0
acetaldehyde	22.4	2.5	161	17.2
propenal	65.3	12.9	5.2	5.2
2-butenal	10.2	1.5	10.2	1.2
butanal	7.3	2.1	5.8	1.5
2-methylpropanal	96.8	2.8	145	4.3
2-methylpropenal	11.6	3.8	18.2	2.5
2-methylbutanal	81.9	1.5	153	3.5
3-methylbutanal	155	2.1	88.5	3.9
pentanal	<0.1	<0.1	<0.1	<0.1
hexanal	34.2	53.6	36.1	8.5
heptanal	25.9	36.3	29.2	8.2
methanol	372	43.2	297	74.7
ethanol	1,183	36.5	1,741	1,595
i-propanol	110	8.2	106	23.3
propanol	36.8	0.8	38.2	2.5
t-butanol	5.4	12.5	15.5	1.2
i-butanol	3.1	0.0	7.4	0.5
2-butanol	3.5	1.1	6.3	0.6
butanol	33.6	6.4	24.3	3.9
3-methylbutanol	8.7	2.4	11.0	1.7
acetone	363	92.7	375	108
2-butanone	18.8	3.7	26.1	2.6
3-buten-2-one	4.4	3.3	4.6	1.7
2,3-butanedione	0.0	0.0	8.4	6.6
methylisobutylketone	8.0	10.8	22.7	5.9
ethylacetate	1.7	1.2	7.0	1.0
benzene	6.2	6.2	6.1	0.8
toluene	26.9	57.3	35.1	9.2
ethylbenzene	2.9	5.9	1.0	0.8
m,p-xylene	3.7	3.6	1.3	2.1
o-xylene	2.1	1.4	0.5	1.1
dichloromethane	4.5	2.7	2.3	1.6
chloroform	3.1	3.9	6.5	18.5
1,1,1-trichloroethane	2.1	0.5	1.0	1.0
trichloroethylene	1.4	0.9	2.1	1.0
tetrachloroethylene	0.2	0.5	7.4	3.4
methylcyclopentane	0.5	0.2	8.7	0.0
methylcyclohexane	1.6	0.5	1.1	0.4
cyclohexane	6.1	3.4	4.6	2.6
hexene	0.0	27.6	3.9	0.0
Thiophene	<0.1	1.4	<0.1	<0.1
octene	<0.1	23.4	<0.1	<0.1
Sum Sulphurs	130	119	620	40
Sum Aldehydes	510	119	652	56
Sum others	2,214	362	2,772	1,872
TOTAL ppb	**2,853**	**600**	**4,045**	**1,969**

Volatile Organic components from Meat Processing Plant

RPDA.303 - Investigation of odourous gas emissions from meat and remaining plants

Plant A	Blood drier	Biofilter	Biofilter	Kill floor
polar column	Outlet	outlet	inlet	air vent
6-Nov-97				
component (ppb)				
hydrogen sulphide	7.9	6.4	5.2	1.5
carbonylsulphide	23.5	48.5	47.2	2.8
sulphurdioxide	<0.1	<0.1	<0.1	<0.1
methylmercaptan	1.8	6.1	190	6.7
dimethylsulphide	0.3	0.3	0.5	0.2
carbondisulphide	0.1	0.1	0.2	0.1
dimethyldisulphide	16.2	11.7	12.3	0.6
dimethyltrisulphide	8.6	4.0	33.9	2.6
acetaldehyde	88.3	2.0	18.2	1.7
propenal	43.9	7.0	23.9	3.3
propanal	13.0	2.5	8.0	1.1
butanal	7.7	2.2	6.8	0.5
2-methylpropanal	97.5	3.3	106	1.9
2-methylpropenal	14.4	4.7	13.5	1.4
2-methylbutanal	41.1	1.3	65.5	0.7
3-methylbutanal	82.1	1.9	140	3.0
pentanal	17.9	4.5	13.7	1.8
hexanal	42.9	33.6	15.9	4.2
heptanal	48.3	36.6	20.6	6.1
octanal	18.8	12.5	19.4	9.1
methanol	209	136	221	76
ethanol	1,660	37	1,486	1,291
i-propanol	112	9.7	113.6	3.0
propanol	13.6	3.6	46.6	2.0
acetone	304	64.5	249	58.7
2-butanone	22.7	4.0	20.2	1.5
benzene	3.2	5.5	4.6	0.3
toluene	5.6	8.0	4.1	0.9
ethylbenzene	4.0	4.6	2.2	0.5
m,p-xylene	4.9	3.1	2.5	1.2
o-xylene	2.7	1.8	2.4	0.7
dichloromethane	2.1	2.7	1.7	0.6
chloroform	3.8	3.9	5.3	7.8
1,1,1-trichloroethane	1.6	1.0	1.3	0.6
Sum Sulphurs	58	77	289	14
Sum Aldehydes	428	110	433	33
Sum others	2,350	286	2,161	1,445
TOTAL ppb	**2,836**	**473**	**2,883**	**1,493**

Volatile Organic components from Meat Processing Plant

Plant A	Biofilter	Biofilter	Cooker room	Kill floor
nonpolar column	outlet	inlet	exhaust	air vent
18-Dec-97				
component (ppb)				
hydrogen sulphide	<0.1	<0.1	<0.1	<0.1
carbonylsulphide	80.9	57.8	13.8	3.2
sulphurdioxide	0.2	<0.1	0.1	<0.1
methylmercaptan	13.9	<0.1	79.7	5.4
dimethylsulphide	9.7	2.4	1.2	0.0
carbondisulphide	22.8	16.6	2.5	1.6
ethylmercaptan	0.7	<0.1	0.3	<0.1
i-propylmercaptan	<0.1	<0.1	0.0	<0.1
propylmercaptan	<0.1	<0.1	<0.1	<0.1
dimethyldisulphide	18.0	10.8	0.8	0.3
dimethyltrisulphide	0.5	<0.1	<0.1	<0.1
acetaldehyde	13.6	11.1	66.4	5.4
propenal	6.7	16.5	6.3	1.6
2-butenal	0.7	2.2	10.8	0.1
butanal	2.4	0.5	5.0	0.7
2-methylpropanal	4.1	51.7	77.4	1.3
2-methylpropenal	7.5	20.0	3.4	1.2
2-methylbutanal	0.6	11.1	15.2	0.2
3-methylbutanal	1.3	53.6	60.1	0.7
pentanal	11.6	4.3	5.2	2.1
hexanal	3.9	3.5	9.7	2.6
heptanal	0.9	6.9	5.9	0.9
methanol	474	551	380	118
ethanol	314	542	131	48.4
i-propanol	76.9	144	22.9	7.0
propanol	76.5	46.8	20.4	1.0
t-butanol	<0.1	<0.1	<0.1	<0.1
i-butanol	<0.1	<0.1	<0.1	<0.1
2-butanol	<0.1	<0.1	2.5	<0.1
butanol	<0.1	<0.1	<0.1	<0.1
3-methylbutanol	1.7	2.3	0.4	<0.1
acetone	176	566	253	48.6
2-butanone	226	33.7	13.5	2.0
3-buten-2-one	18.1	12.4	4.3	1.9
2,3-butanedione	2.8	6.6	40.3	2.0
methylisobutylketone	4.9	33.4	1.1	1.3
ethylacetate	45.8	7.2	2.0	0.7
benzene	14.8	27.5	4.4	4.9
toluene	55.5	7.0	3.7	7.7
ethylbenzene	3.4	0.8	0.5	0.2
m,p-xylene	7.4	0.8	1.2	0.7
o-xylene	3.0	0.2	0.6	0.2
dichloromethane	83.7	0.5	0.7	0.4
chloroform	14.4	1.9	0.9	6.5
1,1,1-trichloroethane	23.6	0.4	0.5	0.1
trichloroethylene	37.7	<0.1	0.1	0.0
tetrachloroethylene	0.3	<0.1	<0.1	<0.1
methylcyclopentane	12.4	0.5	0.2	0.4
methylcyclohexane	1.1	<0.1	<0.1	<0.1
cyclohexane	<0.1	<0.1	<0.1	<0.1
hexene	<0.1	<0.1	<0.1	<0.1
Thiophene	<0.1	<0.1	<0.1	<0.1
octene	<0.1	<0.1	<0.1	<0.1
Sum Sulphurs	147	88	99	11
Sum Aldehydes	53	181	265	17
Sum others	1,675	1,985	884	252
TOTAL ppb	**1,875**	**2,254**	**1,248**	**279**

Volatile Organic components from Meat Processing Plant

RPDA.303 - Investigation of odourous gas emissions from meat and remaining plants

Plant A	Biofilter	Biofilter	Cooker room	Kill floor
polar column	outlet	inlet	exhaust	air vent
18-Dec-97				
component (ppb)				
hydrogen sulphide	4.0	2.9	<0.1	<0.1
carbonylsulphide	39.3	34.7	7.1	13.0
sulphurdioxide	<0.1	<0.1	0.0	<0.1
methylmercaptan	42.3	10.7	25.8	4.6
dimethylsulphide	0.4	0.1	0.1	0.0
carbondisulphide	0.0	0.5	0.0	<0.1
dimethyldisulphide	18.0	11.2	7.1	0.7
dimethyltrisulphide	1.8	2.3	2.6	0.3
acetaldehyde	9.0	103	4.8	1.5
propenal	3.3	10.1	6.8	2.3
propanal	11.8	34.7	13.7	1.1
butanal	18.4	5.6	2.8	0.4
2-methylpropanal	2.1	66.6	46.0	0.8
2-methylpropenal	1.8	11.9	3.2	0.9
2-methylbutanal	0.8	11.5	37.8	0.8
3-methylbutanal	3.0	63.9	119	3.1
pentanal	6.8	8.5	22.4	2.8
hexanal	5.6	2.9	4.0	0.4
heptanal	16.5	12.4	19.5	3.0
octanal	7.7	11.6	14.2	2.8
methanol	160	237	83.2	40.0
ethanol	19.1	224	74.1	24.3
i-propanol	7.0	50.9	21.0	4.3
propanol	0.6	4.6	5.0	1.1
acetone	34.8	377	112	19.0
2-butanone	43.2	56.7	135	63.1
benzene	18.3	9.0	22.0	7.4
toluene	5.6	9.9	5.0	2.8
ethylbenzene	0.6	1.0	0.3	0.1
m,p-xylene	0.8	0.9	0.5	0.1
o-xylene	1.1	0.7	0.4	0.1
dichloromethane	1.2	1.5	1.3	0.5
chloroform	1.5	1.8	1.2	2.9
1,1,1-trichloroethane	0.5	1.1	0.8	0.5
Sum Sulphurs	106	62	43	19
Sum Aldehydes	87	343	294	20
Sum others	294	977	461	166
TOTAL ppb	**487**	**1,382**	**798**	**204**

Volatile Organic components from Meat Processing Plant

Plant B	Cooker Gas	Press Air	Blood Drier	DAF Tank	Tallow Boiling
nonpolar column			Outlet		Tank
19-Nov-97					
component (ppb)	Concentration				
hydrogen sulphide	<0.1	217	140	54	260
carbonylsulphide	1,203	228	10.5	5.8	118
sulphurdioxide	<0.1	<0.1	<0.1	0.5	<0.1
methylmercaptan	3,591	3,941	29.5	40.6	3,059
dimethylsulphide	296	19.4	0.2	0.5	10.3
carbondisulphide	119	71.9	3.3	6.6	5.1
ethylmercaptan	12.3	47.2	0.2	0.3	23.4
i-propylmercaptan	<0.1	<0.1	<0.1	<0.1	<0.1
propylmercaptan	<0.1	<0.1	<0.1	<0.1	<0.1
dimethyldisulphide	289	36.7	1.5	1.2	164.3
dimethyltrisulphide	<0.1	<0.1	<0.1	<0.1	<0.1
acetaldehyde	689	841	70.6	23.2	<0.1
propenal	44.8	62	4.8	4.7	217
2-butenal	35.8	54	1.6	2.9	142
butanal	72.1	18	2.0	0.6	247
2-methylpropanal	5,561	1,463	5.4	5.1	2,243
2-methylpropenal	41.3	15.6	3.0	2.2	74.2
2-methylbutanal	5,666	1,481	8.1	8.6	4,018
3-methylbutanal	11,547	2,441	6.9	17.6	9,060
pentanal	4,950	244	24.1	21.5	3,925
hexanal	190.5	95.7	12.5	5.1	987
heptanal	38.6	22.1	2.2	13.7	239
methanol	1,871	1,292	108	72.5	82.5
ethanol	1,712	11,416	260	334	113
i-propanol	552	537	14.3	20.4	83
propanol	238	111	1.9	7.5	19
t-butanol	8	7	0.4	0.3	2
i-butanol	20	14	13.1	10.5	8
2-butanol	7	9	0.2	0.5	9
butanol	66	79	4.8	2.4	31
3-methylbutanol	85	25	1.4	1.6	116
acetone	7,929	5,297	154	808	5,762
2-butanone	266	297	4.8	3.5	355
3-buten-2-one	67.4	13.2	4.4	2.8	86.0
2,3-butanedione	791	215	12.3	11.2	442
methylisobutylketone	59.0	43.8	30.2	13.1	67.9
ethylacetate	9.5	11.1	2.3	2.1	8.8
benzene	128	91.1	24.0	11.7	9.4
toluene	192	44	38	20	117
ethylbenzene	5.2	0.3	0.9	0.7	4.7
m,p-xylene	10.7	1.1	1.8	1.9	13.1
o-xylene	3.0	0.4	0.4	0.9	2.6
dichloromethane	75.3	37.2	8.8	16.5	11.1
chloroform	19.8	13.6	1.1	2.4	2.1
1,1,1-trichloroethane	14.8	40.2	0.2	0.3	1.1
trichloroethylene	23.3	14.9	0.2	2.0	89.0
tetrachloroethylene	10.6	1.0	<0.1	0.0	<0.1
methylcyclopentane	<0.1	<0.1	<0.1	<0.1	<0.1
methylcyclohexane	<0.1	<0.1	<0.1	<0.1	<0.1
cyclohexane	<0.1	<0.1	<0.1	<0.1	<0.1
hexene	<0.1	<0.1	<0.1	<0.1	<0.1
Thiophene	<0.1	<0.1	<0.1	<0.1	<0.1
octene	<0.1	<0.1	<0.1	<0.1	<0.1
Sum Sulphurs	5,509	4,562	185	110	3,640
Sum Aldehydes	28,836	6,737	141	105	21,152
Sum others	14,163	19,612	687	1,348	7,437
TOTAL ppb	**48,508**	**30,910**	**1,014**	**1,563**	**32,229**

Volatile Organic components from Meat Processing Plant

RPDA 303 - Investigation of odourous gas emissions from meat and remaining plants

Plant B	Cooker Gas	Press Air	Blood Drier	DAF Tank	Tallow Boiling
polar column			Outlet		Tank
19-Nov-97					
component (ppb)	Concentration				
hydrogen sulphide	1.3	0.9	N/A	N/A	4.1
carbonylsulphide	102	33.4	N/A	N/A	59.4
sulphurdioxide	0.3	<0.1	N/A	N/A	0.3
methylmercaptan	12.7	6.3	N/A	N/A	10.6
dimethylsulphide	14.3	3.6	N/A	N/A	2.9
carbondisulphide	0.2	0.0	N/A	N/A	0.7
dimethyldisulphide	53.9	33.3	N/A	N/A	215
dimethyltrisulphide	30.1	39.2	N/A	N/A	138
acetaldehyde	2,866	418	N/A	N/A	482
propenal	<0.1	<0.1	N/A	N/A	<0.1
propanal	222	270	N/A	N/A	590
butanal	40.9	25.5	N/A	N/A	145
2-methylpropanal	664	435	N/A	N/A	865
2-methylpropenal	14.8	7.8	N/A	N/A	30.3
2-methylbutanal	789	334	N/A	N/A	764
3-methylbutanal	1,147	560	N/A	N/A	726
pentanal	362	44.7	N/A	N/A	602
hexanal	91.0	60.9	N/A	N/A	633
heptanal	54.0	52.0	N/A	N/A	320
octanal	14.5	14.6	N/A	N/A	213
methanol	612	188	N/A	N/A	430
ethanol	367	53.0	N/A	N/A	154
i-propanol	175	86.5	N/A	N/A	40.0
propanol	69.5	16.1	N/A	N/A	84.5
acetone	2,081	638	N/A	N/A	1,780
2-butanone	115	270	N/A	N/A	222
benzene	1.1	5.3	N/A	N/A	9.1
toluene	25.1	6.5	N/A	N/A	19.3
ethylbenzene	2.1	2.6	N/A	N/A	4.4
m,p-xylene	6.1	6.0	N/A	N/A	11.7
o-xylene	6.3	4.2	N/A	N/A	9.0
dichloromethane	14.4	19.7	N/A	N/A	5.2
chloroform	6.4	13.2	N/A	N/A	2.6
1,1,1-trichloroethane	4.2	1.7	N/A	N/A	0.9
Sum Sulphurs	214	117	0	0	431
Sum Aldehydes	6,265	2,223	0	0	5,372
Sum others	3,485	1,311	0	0	2,773
TOTAL ppb	**9,965**	**3,650**	**0**	**0**	**8,576**

Volatile Organic components from Meat Processing Plant

Plant B	Cooker Gas	Press Air	Blood Drier Outlet	Tallow Boiling Tank
nonpolar column				
19-Dec-97				
component (ppb)	Concentration			
hydrogen sulphide	<0.1	<0.1	390	<0.1
carbonylsulphide	75	183	57.2	69
sulphurdioxide	<0.1	<0.1	4.5	<0.1
methylmercaptan	103	1,944	674	537
dimethylsulphide	29.5	30.8	1.5	22.7
carbondisulphide	47.3	25.6	9.2	14.1
ethylmercaptan	20.2	<0.1	<0.1	43.3
i-propylmercaptan	<0.1	<0.1	<0.1	<0.1
propylmercaptan	0.9	<0.1	0.5	<0.1
dimethyldisulphide	173	19.6	12.9	28.7
dimethyltrisulphide	<0.1	<0.1	<0.1	<0.1
acetaldehyde	<0.1	19,200	<0.1	<0.1
propenal	117	27	161.3	181
2-butenal	<0.1	360	19.3	56
butanal	79.2	41	20.9	79
2-methylpropanal	1,223	1,624	52.8	2,539
2-methylpropenal	68.8	14.1	8.4	26.5
2-methylbutanal	730	575	16.6	556
3-methylbutanal	1,905	860	42.5	1,421
pentanal	<0.1	65	48.3	628
hexanal	54.6	26.0	29.1	352
heptanal	56.2	10.8	49.8	191
methanol	3,844	3,503	273	425
ethanol	808	237	56	226
i-propanol	215	124	58.5	432
propanol	311	53	10.1	18
t-butanol	93	12	2.6	3
i-butanol	77	0	2.5	8
2-butanol	46	5	1.3	6
butanol	<0.1	<0.1	1.3	<0.1
3-methylbutanol	<0.1	7	6.7	5
acetone	2,402	1,670	540	3,845
2-butanone	166	213	23.1	172
3-buten-2-one	86.6	17.8	7.3	75.9
2,3-butanedione	770	230	21.7	493
methylisobutylketone	15.9	0.3	2.5	5.0
ethylacetate	33.6	0.2	3.1	82.9
benzene	144	38.7	2.1	18.8
toluene	37	12	8	25
ethylbenzene	7.1	1.2	0.6	3.3
m,p-xylene	19.1	3.5	1.1	9.8
o-xylene	8.5	0.9	0.4	3.3
dichloromethane	15.0	4.5	1.0	4.7
chloroform	3.2	0.4	0.1	0.7
1,1,1-trichloroethane	5.7	1.0	0.4	4.5
trichloroethylene	15.8	1.2	0.2	<0.1
tetrachloroethylene	0.6	<0.1	<0.1	<0.1
methylcyclopentane	<0.1	<0.1	<0.1	7.3
methylcyclohexane	0.4	<0.1	<0.1	0.6
cyclohexane	119	<0.1	<0.1	<0.1
hexene	<0.1	<0.1	<0.1	<0.1
Thiophene	<0.1	<0.1	<0.1	<0.1
octene	<0.1	<0.1	<0.1	<0.1
Sum Sulphurs	449	2,203	1,150	715
Sum Aldehydes	4,234	22,803	449	6,029
Sum others	9,245	6,135	1,024	5,875
TOTAL ppb	**13,929**	**31,141**	**2,622**	**12,619**

Volatile Organic components from Meat Processing Plant

Plant B	Cooker Gas	Press Air	Blood Drier	Tallow Boiling
polar column			Outlet	Tank
19-Dec-97				
component (ppb)	Concentration			
hydrogen sulphide	<0.1	331	55.2	53.2
carbonylsulphide	81.6	67.1	3.8	93.3
sulphurdioxide	<0.1	<0.1	<0.1	<0.1
methylmercaptan	367	3,831	113	4,369
dimethylsulphide	5.4	7.6	0.7	16.9
carbondisulphide	2.3	0.9	0.0	0.3
dimethyldisulphide	325	212	10.5	163
dimethyltrisulphide	40.3	20.0	1.7	17.9
acetaldehyde	3,828	4,364	408	337
propenal	<0.1	<0.1	<0.1	<0.1
propanal	42.0	125	<0.1	217
butanal	32.9	178	11.7	76.3
2-methylpropanal	258	665	2.5	833
2-methylpropenal	7.2	6.3	0.9	5.1
2-methylbutanal	392	949	1.8	667
3-methylbutanal	345	960	2.7	943
pentanal	50.3	56.1	1.9	97.9
hexanal	7.8	11.4	1.4	83.5
heptanal	40.3	29.5	2.0	38.8
octanal	20.5	25.6	0.6	2.6
methanol	293	1,245	79.8	504
ethanol	7,819	21,957	614	7,418
i-propanol	146	271	15.7	139
propanol	326	1,160	30.2	337
acetone	587	649	31.5	840
2-butanone	121	279	14.3	220
benzene	115	100	9.4	94.7
toluene	57.6	16.6	4.3	11.8
ethylbenzene	5.3	1.0	0.9	2.0
m,p-xylene	24.5	2.1	2.5	4.8
o-xylene	12.8	2.5	1.2	4.1
dichloromethane	4.9	5.3	0.4	2.4
chloroform	8.6	11.1	0.6	8.6
1,1,1-trichloroethane	6.3	1.5	0.3	1.2
Sum Sulphurs	822	4,470	185	4,714
Sum Aldehydes	5,024	7,369	434	3,302
Sum others	9,527	25,702	805	9,588
TOTAL ppb	**15,373**	**37,541**	**1,424**	**17,604**

Plant C	RT 2	Scrubber	RT 3	Scrubber
nonpolar column		Outlet		Inlet
26-Nov-97				
component (ppb)	Concentration			
hydrogen sulphide	0.05	102	54.4	35.1
carbonylsulphide	5.2	61.2	5.4	112
sulphurdioxide	<0.1	<0.1	<0.1	<0.1
methylmercaptan	182	5,388	177	4,908
dimethylsulphide	1.4	45.9	2.9	35.0
carbondisulphide	7.7	33.9	2.9	66.3
ethylmercaptan	<0.1	<0.1	<0.1	<0.1
i-propylmercaptan	<0.1	<0.1	<0.1	2
propylmercaptan	<0.1	<0.1	<0.1	<0.1
dimethyldisulphide	9.4	168	9.1	231
dimethyltrisulphide	0.1	0.5	0.3	2.5
acetaldehyde	3.1	207	9.7	876
propenal	1.9	5.1	3.2	6.9
2-butenal	2.0	1.8	0.5	9.7
butanal	3.8	32.4	1.5	38.5
2-methylpropanal	30.0	892	3.1	1,164
2-methylpropenal	1.8	7.4	1.1	5.2
2-methylbutanal	54	1,698	2.2	1,458
3-methylbutanal	51.2	1,749	4.1	1,894
pentanal	0.9	13.1	0.8	48.0
hexanal	10.9	106	4.0	232
heptanal	0.02	29.6	7.4	97.3
acetic acid	<0.1	<0.1	<0.1	<0.1
methanol	68.1	1,080	92.8	1,179
ethanol	471	11,405	745	11,807
i-propanol	21.5	193	9.5	271
propanol	33.2	650	28	649
t-butanol	0.8	5.3	3.2	0.4
i-butanol	7.1	17.3	1.4	54.4
2-butanol	16.5	63.3	3.6	79.3
butanol	10.1	897	14.7	984
3-methylbutanol	2.5	52.3	1.3	67.6
acetone	74.6	1,446	59.5	1,312
2-butanone	20.1	195	8.7	231
3-buten-2-one	1.2	0.3	0.3	0.3
2,3-butanedione	9.1	111	4.3	0.3
methylisobutylketone	12.5	70.1	9.8	57.3
ethylacetate	3.8	15.4	2.2	19.4
benzene	23.7	162	5.9	18.3
toluene	14.4	43.3	14.2	35.6
ethylbenzene	2.7	6.3	3.6	7.6
m,p-xylene	6.9	21.1	11.8	22.6
o-xylene	1.0	11.5	4.5	6.9
dichloromethane	1.7	9.5	1.0	5.0
chloroform	1.0	11.0	0.6	12.2
1,1,1-trichloroethane	7.6	2.1	0.1	1.8
trichloroethylene	1.3	4.3	0.4	9.9
tetrachloroethylene	0.3	0.2	0.0	0.2
methylcyclopentane	0.0	0.3	0.0	0.3
methylcyclohexane	0.0	0.2	0.0	0.2
cyclohexane	0.8	0.3	0.0	12.6
hexene	0.0	0.4	0.8	0.4
Sum Sulphurs	206	5,799	252	5,392
Sum Aldehydes	160	4,742	38	5,829
Sum others	813	16,470	1,027	16,846
TOTAL ppb	**1,179**	**27,012**	**1,317**	**28,067**

Volatile Organic components from Meat Processing Plant

Plant C	RP 2	Scrubber	RP 3	Scrubber
polar column		Outlet		Inlet
26-Nov-97				
component (ppb)	Concentration			
hydrogen sulphide	<0.1	331	55.2	53.2
carbonylsulphide	8.2	67.1	3.8	93.3
sulphurdioxide	<0.1	<0.1	<0.1	<0.1
methylmercaptan	36.7	3,831	113	4,369
dimethylsulphide	0.5	7.6	0.7	16.9
carbondisulphide	0.2	0.9	0.0	0.3
dimethyldisulphide	32.5	212	10.5	163
dimethyltrisulphide	4.0	20.0	1.7	17.9
acetaldehyde	16.7	2,710	42.5	3,954
propenal	<0.1	<0.1	<0.1	<0.1
propanal	4.2	125	<0.1	217
butanal	3.3	178	11.7	76.3
2-methylpropanal	25.8	665	2.5	833
2-methylpropenal	0.7	6.3	0.9	5.1
2-methylbutanal	39.2	949	1.8	667
3-methylbutanal	34.5	960	2.7	943
pentanal	5.0	56.1	1.9	97.9
hexanal	0.8	11.4	1.4	83.5
heptanal	4.0	29.5	2.0	38.8
octanal	2.0	25.6	0.6	2.6
methanol	29.3	1,245	79.8	504
ethanol	782	21,957	614	7,418
i-propanol	14.6	271	15.7	139
propanol	32.6	1,160	30.2	337
acetone	58.7	649	31.5	840
2-butanone	12.1	279	14.3	220
benzene	11.5	100	9.4	94.7
toluene	5.8	16.6	4.3	11.8
ethylbenzene	0.5	1.0	0.9	2.0
m,p-xylene	2.5	2.1	2.5	4.8
o-xylene	1.3	2.5	1.2	4.1
dichloromethane	0.5	5.3	0.4	2.4
chloroform	0.9	11.1	0.6	8.6
1,1,1-trichloroethane	0.6	1.5	0.3	1.2
Sum Sulphurs	82	4,470	185	4,714
Sum Aldehydes	136	5,715	68	6,919
Sum others	953	25,702	805	9,588
TOTAL ppb	**1,171**	**35,887**	**1,058**	**21,220**

Volatile Organic components from Meat Processing Plant

Plant C	RP 3	Scrubber	RP 3	RP 1	Scrubber
nonpolar column	before ozone	Outlet	after ozone	stack	Inlet
4-Mar-98					
component (ppb)	Concentration				
hydrogen sulphide	22.8	4,226	2.65	<0.05	10,847
carbonylsulphide	3.41	83.5	3.56	22.5	294
sulphurdioxide	0.10	<0.06	0.03	1,996	<0
methylmercaptan	94.8	3,104	37.8	<0.04	8,880
dimethylsulphide	0.42	14.1	0.22	0.43	17.6
carbondisulphide	1.07	0.12	0.31	0.14	7.26
ethylmercaptan	0.12	5.49	<0	0.09	2.73
i-propylmercaptan	<0	<0.19	<0	<0.02	<0
propylmercaptan	<0	0.79	<0	<0.05	<0
dimethyldisulphide	1.32	23.4	1.25	0.88	27.83
dimethyltrisulphide	<0.02	<0.11	<0.02	<0.02	<0.5
acetaldehyde	3.25	24.0	0.81	1.80	49.9
propenal	0.84	13.18	1.67	8.04	11.84
2-butenal	0.20	1.88	0.37	0.64	2.96
butanal	0.40	12.27	0.20	0.99	21.8
2-methylpropanal	1.05	404	1.29	64.2	765
2-methylpropenal	0.19	2.08	0.20	1.09	2.07
2-methylbutanal	0.62	333	0.76	29.8	309
3-methylbutanal	1.08	1,700	0.68	72.0	1,565
pentanal	0.09	0.57	0.03	0.34	20.6
hexanal	1.91	29.8	5.25	2.42	13.0
heptanal	<0.02	4.13	<0.02	<0.02	<0.42
acetic acid	<0	<0	<0	<0	<0
methanol	43.3	43.4	11.8	53.1	1,580
ethanol	383	5,797	436	423	5,422
i-propanol	3.53	80	5.47	24.9	130
propanol	48	1,071	75	221	1,412
t-butanol	0.27	1.21	0.28	7.93	1.78
i-butanol	0.41	35.1	0.08	2.23	<0.91
2-butanol	1.63	52.4	3.15	5.60	41.3
butanol	0.93	5.94	0.97	3.30	5.74
3-methylbutanol	<0.04	8.45	0.07	1.56	<0.76
acetone	25.8	842	17.18	239	969
2-butanone	1.88	106	1.64	8.54	186
3-buten-2-one	0.15	0.63	0.15	0.81	<0.77
2,3-butanedione	2.67	180	4.40	4.02	220
methylisobutylketone	7.93	17.6	17.5	6.96	6.49
ethylacetate	0.16	63.6	3.05	1.67	24.6
benzene	0.37	2.53	0.62	3.52	32.9
toluene	1.58	3.35	3.21	4.90	2.23
ethylbenzene	0.14	0.28	0.09	0.11	<0.15
m,p-xylene	0.20	0.61	0.26	0.25	<0.15
o-xylene	0.10	0.41	0.07	0.08	<0.15
dichloromethane	0.13	0.27	0.08	0.14	0.93
chloroform	1.58	9.39	0.84	0.67	9.19
1,1,1-trichloroethane	<0.02	0.22	<0.02	<0.02	<0.48
trichloroethylene	0.11	1.02	0.06	0.11	1.78
tetrachloroethylene	<0.02	<0.1	<0.02	<0.02	<0.44
methylcyclopentane	<0.03	0.89	<0.03	0.72	1.41
methylcyclohexane	<0.02	<0.1	<0.02	0.04	<0.46
cyclohexane	0.51	<0.17	0.71	<0.03	1.49
hexene	0.80	3.34	1.78	7.61	4.08
Sum Sulphurs	124	7,458	46	2,020	20,075
Sum Aldehydes	10	2,525	11	181	2,761
Sum others	525	8,326	585	1,021	10,054
TOTAL ppb	**659**	**18,309**	**642**	**3,223**	**32,891**

Volatile Organic components from Meat Processing Plant

Plant D	Blood Tank	Waste water	Incinerator	Hammermill	Tallow Day
nonpolar column		Shaker screen		room	Tank
15-Nov-97					
component (ppb)	Concentration				
hydrogen sulphide	96,598	283	167,033	393	100
carbonylsulphide	152	15.7	31,191	18.2	18.2
sulphurdioxide	<0.1	<0.1	<0.1	<0.1	<0.1
methylmercaptan	53,187	521	429,414	319	125
dimethylsulphide	3,365	103	3,915	1.2	0.6
carbondisulphide	332	15.1	324	13.6	10.2
ethylmercaptan	<0.1	<0.1	<0.1	<0.1	<0.1
i-propylmercaptan	21.7	0.4	11.8	0.7	0.4
propylmercaptan	9.3	2.8	20.6	0.0	0.0
butylmercaptan	28.9	0.0	618	0.0	0.0
dimethyldisulphide	1,183	8.4	11,442	7.6	2.8
dimethyltrisulphide	243	2.4	1,072	0.0	0.5
acetaldehyde	2,107	13.9	5,497	3.3	14.1
propenal	18.5	8.8	166	11.6	6.5
2-butenal	0.6	1.2	14,810	0.1	2.8
butanal	6.6	3.6	1,445	3.8	7.2
2-methylpropanal	21.7	16.7	124,772	36.3	61.9
2-methylpropenal	6.3	3.0	1,611	4.7	2.4
2-methylbutanal	4.1	20.5	222,899	50.4	120
3-methylbutanal	15.7	20.9	164,736	119	171
pentanal	176	4.3	10,918	3.7	25.2
hexanal	25.2	12.4	3,785	26.0	28.9
heptanal	7.2	3.0	1,149	9.0	14.7
acetic acid	<0.1	<0.1	<0.1	<0.1	<0.1
methanol	297	222	43,426	284	354
ethanol	14,170	6,148	208,224	466	435
i-propanol	805	271	22,517	20.8	67.5
propanol	469	265	7,749	20.3	11.8
t-butanol	7.1	15.1	121	10.6	1.0
i-butanol	86.3	30.8	752	2.4	1.9
2-butanol	7.0	30.6	1,197	1.8	3.5
butanol	79.7	69.9	10.4	19.2	6.6
3-methylbutanol	2.1	9.8	908	3.7	4.4
acetone	1,573	161.1	42,210	325	176
2-butanone	42.6	14.3	4,956	13.0	9.3
3-buten-2-one	1.4	1.0	39.5	1.2	1.8
2,3-butanedione	26.4	11.4	1,252	18.8	11.4
methylisobutylketone	95.7	37.2	1,537	8.5	36.0
ethylacetate	67.0	11.5	728	3.1	2.9
benzene	1.5	0.8	1,293	1.7	1.2
toluene	41.5	32.6	2,073	93.6	33.1
ethylbenzene	0.3	0.4	70.3	1.6	0.4
m,p-xylene	0.6	1.3	214	3.7	1.2
o-xylene	0.4	0.4	50.9	1.4	0.4
dichloromethane	3.8	1.0	117	5.9	1.4
chloroform	6.8	0.6	148	23.9	0.8
1,1,1-trichloroethane	0.4	0.4	51.1	2.4	0.2
trichloroethylene	0.2	0.3	234	2.3	0.7
tetrachloroethylene	0.1	0.2	8.7	0.2	0.0
methylcyclopentane	0.1	1.0	200	5.5	1.3
methylcyclohexane	0.6	2.1	9.8	2.4	1.0
cyclohexane	3.7	0.5	107	4.5	2.8
hexene	7.4	3.3	549	0.1	3.9
Sum Sulphurs	155,120	951	645,043	754	257
Sum Aldehydes	2,389	108	551,788	268	455
Sum others	17,797	7,345	340,752	1,348	1,171
TOTAL ppb	**175,306**	**8,404**	**1,537,583**	**2,370**	**1,884**

Volatile Organic components from Meat Processing Plant

Plant D	BNR plant	Biofilter	Red Meat	Biofilter	Fish pile
nonpolar column		inlet	receival	outlet	
15-Nov-97					
component (ppb)	Concentration				
hydrogen sulphide	99.7	67.8	249	1.7	61.9
carbonylsulphide	15.2	126	12.8	90.9	14.2
sulphurdioxide	<0.1	<0.1	<0.1	<0.1	<0.1
methylmercaptan	1,438	548	245	33.9	257
dimethylsulphide	30.9	6.4	7.2	0.0	26.7
carbondisulphide	16.7	19.9	10.4	6.4	5.3
ethylmercaptan	<0.1	<0.1	<0.1	<0.1	<0.1
i-propylmercaptan	0.3	0.0	0.0	0.0	0.0
propylmercaptan	0.2	0.0	0.0	0.0	0.0
dimethyldisulphide	40.3	7.3	3.4	0.6	6.6
dimethyltrisulphide	13.9	1.6	3.1	0.0	1.1
acetaldehyde	8.4	16.7	9.3	4.7	7.1
propenal	7.5	9.6	9.6	6.5	16.4
2-butenal	1.5	2.7	1.4	0.5	1.5
butanal	6.7	7.8	2.4	0.7	2.6
2-methylpropanal	13.6	284	5.8	1.7	19.2
2-methylpropenal	2.5	2.9	2.1	1.3	2.5
2-methylbutanal	9.2	296	2.5	1.0	10.0
3-methylbutanal	28.7	470	5.4	2.7	28.5
pentanal	5.6	26.1	1.8	1.3	8.6
hexanal	16.4	55.4	4.3	5.4	14.5
heptanal	11.4	24.6	2.6	3.6	7.6
methanol	227	371	123	138	318
ethanol	2,155	581	533	72.2	2,205
i-propanol	159	32.1	122	44.2	185
propanol	79.0	17.2	19.6	1.3	31.4
t-butanol	1.3	0.2	0.7	1.7	11.7
i-butanol	88.8	1.5	2.1	0.3	2.4
2-butanol	13.8	2.5	4.1	0.7	15.0
butanol	12.8	2.1	4.9	1.6	13.2
3-methylbutanol	2.7	0.1	0.7	0.0	2.1
acetone	293	255	128	59.1	186
2-butanone	23.1	34.0	4.0	24.7	15.8
3-buten-2-one	0.7	4.8	1.2	0.3	16.5
2,3-butanedione	40.3	8.4	12.1	7.9	20.7
methylisobutylketone	144	5.7	5.6	4.0	16.8
ethylacetate	2.7	1.3	2.7	1.1	6.1
benzene	2.1	0.3	0.7	0.9	1.9
toluene	25.1	18.3	55.9	20.1	331
ethylbenzene	0.5	0.3	0.2	0.5	0.9
m,p-xylene	1.7	1.2	0.7	1.5	2.8
o-xylene	0.6	0.4	0.3	0.5	1.0
dichloromethane	1.7	2.0	1.2	1.8	55.3
chloroform	1.3	0.3	0.4	0.6	9.3
1,1,1-trichloroethane	0.5	0.0	0.2	0.2	3.1
trichloroethylene	0.5	0.8	0.2	0.3	2.2
tetrachloroethylene	0.5	32.0	0.0	0.0	1.2
methylcyclopentane	9.0	1.7	0.3	0.8	12.1
methylcyclohexane	1.1	0.2	0.3	0.0	0.6
cyclohexane	5.8	0.3	0.2	0.0	10.6
hexene	4.5	1.9	1.1	1.2	12.5
Sum Sulphurs	1656	777	531	133	373
Sum Aldehydes	111	1195	47	29	118
Sum others	3,311	1,377	1,025	386	3,490
TOTAL ppb	**5,078**	**3,349**	**1,603**	**549**	**3,981**

Volatile Organic components from Meat Processing Plant

Plant D	Biofilter	Biofilter	BNR plant	Red Meat	Blood	Incinerator
nonpolar column	inlet	outlet		cooker	cooker	
23-Jan-98						
component (ppb)	concentration					
hydrogen sulphide	553	7.4	70.6	210	650	475,739
carbonylsulphide	35.8	39.5	5.9	28.5	26.1	5,724
sulphurdioxide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
methylmercaptan	3,439	694	56.6	880	5,103	214,221
dimethylsulphide	18.4	25.1	1.6	29.4	22.8	2,993
carbondisulphide	7.1	14.7	2.3	14.6	19.0	1,361
ethylmercaptan	10.1	30.2	1.4	35.8	4.6	1,264
i-propylmercaptan	0.2	0.4	<0.1	3.0	0.4	165
propylmercaptan	1.5	1.3	0.1	<0.1	0.2	172
dimethyldisulphide	141	67.2	4.5	21.7	102	3,112
dimethyltrisulphide	1.5	5.8	<0.1	<0.1	<0.1	69.7
acetaldehyde	44.4	9.5	5.6	109	111	6,439
propenal	24.3	10.3	7.5	27.5	20.0	1,192
2-butenal	2.2	1.2	0.6	1.2	1.2	13.4
butanal	39.8	0.7	1.3	5.3	5.6	510
2-methylpropanal	234	2.9	2.2	134	30.3	56,911
2-methylpropenal	4.8	1.4	2.1	3.9	3.9	189
2-methylbutanal	101	0.7	1.4	23.2	5.2	58,357
3-methylbutanal	394	2.3	2.6	135	35.4	92,153
pentanal	20.0	3.6	2.8	20.0	45.3	1,626
hexanal	32.4	4.1	42.4	20.8	12.4	1,877
heptanal	25.1	4.7	15.0	<0.1	<0.1	1,298
methanol	600	168	353	330	302	11,307
ethanol	8,001	843	593	1,832	11,538	22,591
i-propanol	183	10.4	40.7	93.6	213	1,774
propanol	301	13.9	44.6	76.1	362	2,438
t-butanol	10.1	1.1	2.7	1.5	1.3	204
i-butanol	78.0	2.9	9.4	7.8	73.6	223
2-butanol	30.6	1.2	4.0	5.1	24.5	187
butanol	141	3.9	3.5	6.9	97.6	4,468
3-methylbutanol	12.6	0.9	1.7	4.5	8.0	118
acetone	357	47.0	97.6	305	191	30,719
2-butanone	137	2.6	3.4	9.7	10.1	1,749
3-buten-2-one	2.6	1.7	0.8	2.9	2.1	63.2
2,3-butanedione	32.5	9.4	5.4	32.9	24.8	656
methylisobutylketone	28.8	2.2	11.1	2.5	28.0	432
ethylacetate	140	4.1	1.8	11.9	113	359
benzene	4.0	1.9	2.3	11.8	19.8	271
toluene	13.4	9.5	8.0	10.1	8.8	378
ethylbenzene	1.6	0.9	0.6	1.0	0.7	68.9
m,p-xylene	4.7	2.2	1.4	2.4	1.5	169
o-xylene	2.0	1.0	0.5	0.8	0.5	66.8
dichloromethane	7.4	1.0	0.8	2.1	1.5	157
chloroform	0.9	0.2	0.0	0.3	0.1	46.8
1,1,1-trichloroethane	0.4	0.3	0.1	<0.1	0.5	109
trichloroethylene	3.3	0.7	0.3	1.7	1.4	123
tetrachloroethylene	6.0	8.9	0.1	<0.1	<0.1	1.3
methylcyclopentane	2.1	0.4	4.1	<0.1	3.2	32.6
methylcyclohexane	0.7	0.3	0.1	<0.1	<0.1	7.5
cyclohexane	<0.1	1.3	<0.1	<0.1	0.6	<0.1
hexene	8.5	5.8	3.5	10.6	8.8	250
Sum Sulphurs	4208	885	143	1223	5928	704819
Sum Aldehydes	922	41	83	480	271	220565
Sum others	10,117	1,147	1,194	2,764	13,036	78,972
TOTAL ppb	**15,247**	**2,073**	**1,421**	**4,468**	**19,235**	**1,004,356**

Plant D	Biofilter	Biofilter	BNR plant	Red Meat	Blood	Incinerator
polar column	inlet	outlet		cooker	cooker	
23-Jan-98						
component (ppb)	concentration					
hydrogen sulphide	69.0	8.2	5.5	401	4,346	32,629
carbonylsulphide	13.4	19.1	2.4	5.9	79.5	2,060
sulphurdioxide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
methylmercaptan	935	396	21.3	482	33,014	54,815
dimethylsulphide	2.0	14.2	0.9	10.8	11.4	907
carbondisulphide	0.3	4.3	1.3	2.7	23.1	468
dimethyldisulphide	13.9	5.1	1.3	1.3	219	1,904
dimethyltrisulphide	18.3	6.7	1.4	1.4	23.5	1,328
acetaldehyde	353	22.3	1.8	1.7	731	1,006
propenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
propanal	49.5	4.1	6.2	4.9	726	4,846
butanal	9.6	0.5	1.3	3.3	12.0	225
2-methylpropanal	65.9	1.4	1.9	96.2	132	18,789
2-methylpropenal	3.0	1.3	1.1	1.5	8.3	49.9
2-methylbutanal	29.3	0.3	0.5	46.9	73.0	19,242
3-methylbutanal	73.1	0.6	0.6	111	175	34,795
pentanal	11.7	0.6	6.3	9.3	17.9	668
hexanal	4.5	0.8	12.1	3.4	16.7	225
heptanal	7.6	1.5	19.2	6.5	24.6	235
octanal	10.5	1.4	5.6	8.0	9.5	446
methanol	1,092	63.0	168	179	457	2,649
ethanol	2,637	378	366	826	75,567	14,190
i-propanol	96.7	10.7	17.6	81.4	930	1,996
propanol	156	8.1	24.9	77.6	2,493	1,529
acetone	94.8	20.7	42.4	76.0	410	3,478
2-butanone	7.3	0.9	2.3	6.6	55.0	485
benzene	14.9	1.1	2.8	6.3	44.4	279
toluene	2.4	0.6	1.1	1.6	13.7	42.3
ethylbenzene	0.2	0.1	0.1	0.1	1.2	8.1
m,p-xylene	0.8	0.3	0.3	0.4	3.1	19.9
o-xylene	0.7	0.2	0.2	0.4	2.5	161
dichloromethane	13.2	1.6	1.6	2.4	0.9	71.4
chloroform	1.3	0.3	0.1	0.4	3.0	24.9
1,1,1-trichloroethane	2.5	0.4	0.3	0.6	4.4	28.5
Sum Sulphurs	1,052	454	34	905	37,716	94,111
Sum Aldehydes	618	35	57	293	1,925	80,526
Sum others	4,120	487	627	1,259	79,985	24,963
TOTAL ppb	**5,790**	**975**	**718**	**2,456**	**119,626**	**199,600**

Plant E	Drier	Non	Factory air	Drier	Raw
nonpolar column		condensables		Biofilter (out)	materials
17-Oct-97					
component	concentration				
hydrogen sulphide	25.2	29,350	116	50.5	29.1
carbonylsulphide	327	9,531	82.6	141	13.1
sulphurdioxide	2.2	13.6	0.6	0.9	0.3
methylmercaptan	103	15,424	507	<0.1	90.0
dimethylsulphide	0.6	139	3.9	4.7	4.7
carbondisulphide	238	380	18.3	411	0.6
ethylmercaptan	<0.1	831	2.0	<0.1	<0.1
i-propylmercaptan	<0.1	27.9	<0.1	<0.1	<0.1
propylmercaptan	1.3	9.8	<0.1	<0.1	0.1
dimethyldisulphide	1.3	77.4	2.6	1.0	0.8
dimethyltrisulphide	<0.1	<0.1	<0.1	<0.1	<0.1
acetaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1
propenal	150	29	19.1	14.5	7.6
2-butenal	53.1	24.8	4.1	4.9	3.7
butanal	228	58	5.3	3.2	2.2
2-methylpropanal	211	1,720	249	11.4	4.5
2-methylpropenal	29.4	13.8	4.4	6.8	3.7
2-methylbutanal	83.0	3,135	289	4.7	1.1
3-methylbutanal	124	3,839	357	7.7	4.5
pentanal	904	628	84.7	274	8.0
hexanal	597	551	55.1	273	15.0
heptanal	408	303	22.8	78.0	10.5
methanol	396	302	122	106	92.4
ethanol	4,318	1,439	492	95.0	468
i-propanol	29	394	83.7	19.2	35.7
propanol	18	124	20.1	5.1	12.3
t-butanol	5.0	15.2	4.1	2.3	0.5
i-butanol	12.2	38.2	6.5	2.7	1.0
2-butanol	4.4	82.1	4.4	1.0	0.8
butanol	62.7	72.5	6.0	14.5	1.8
3-methylbutanol	43.5	37.3	6.2	5.2	2.4
acetone	1,136	1,805	460	312	109
2-butanone	192	198	45.1	62.8	5.3
3-buten-2-one	129	18.2	6.9	1.6	10.8
2,3-butanedione	126	142	25.4	2.3	16.7
methylisobutylketone	53.0	264	23.0	13.4	10.5
ethylacetate	6.2	39.6	5.0	6.9	3.0
benzene	69.1	96.1	3.9	96.8	2.1
toluene	131	283	81.2	96.9	28.3
ethylbenzene	27.0	102	3.4	11.9	2.4
m,p-xylene	37.8	166	7.5	9.3	4.6
o-xylene	14.6	45.7	2.6	4.8	1.9
dichloromethane	24.7	10.1	53.2	3.2	43.6
chloroform	12.6	48.4	6.9	4.4	9.0
1,1,1-trichloroethane	11.0	4.9	1.2	1.8	2.0
trichloroethylene	11.3	16.0	8.8	2.8	1.2
tetrachloroethylene	1.0	0.3	2.9	0.2	2.7
methylcyclopentane	3.8	21.0	23.8	30.7	5.5
methylcyclohexane	3.2	66.9	30.5	37.3	1.4
cyclohexane	7.7	51.2	35.5	43.1	7.5
hexene	881	8.0	6.4	1,198	9.8
heptene	813	39.1	14.2	1,401	5.3
octene	710	23.8	2.0	884	4.3
nonene	168	7.1	1.4	452	2.1
Sum Sulphurs	699	55,783	734	609	139
Sum Aldehydes	2,789	10,302	1,090	678	61
Sum others	7,767	5,891	1,580	2,191	893
TOTAL (ppb)	**11,254**	**71,977**	**3,403**	**3,478**	**1,092**

Plant E	Drier	Non condensables	Factory air	Drier Biofilter (out)	Raw materials
polar column					
17-Oct-97					
component (ppb)	concentration				
hydrogen sulphide	14.3	9,894	70.0	<0.1	35.8
carbonylsulphide	184	1,475	40.9	37.4	2.8
sulphurdioxide	<0.1	<0.1	<0.1	2.6	1.1
methylmercaptan	20.2	4,396	143	9.7	25.7
dimethylsulphide	<0.1	123	<0.1	<0.1	0.5
carbondisulphide	<0.1	0.7	<0.1	62.6	<0.1
dimethyldisulphide	2.4	63.8	3.5	0.8	0.5
dimethyltrisulphide	2.2	73.6	6.2	0.6	0.3
acetaldehyde	27.7	28.8	6.9	6.1	3.7
propenal	5.1	12.0	2.9	0.9	0.0
propanal	<0.1	<0.1	<0.1	<0.1	<0.1
butanal	59.4	71.3	8.7	17.3	6.5
2-methylpropanal	148	706	137	5.3	2.1
2-methylpropenal	46.0	7.5	2.7	1.0	2.6
2-methylbutanal	72.4	552	126	11.2	1.3
3-methylbutanal	130	1,435	322	21.6	2.4
pentanal	281	96.6	15.2	46.2	7.9
hexanal	438	176	156	132	17.6
heptanal	345	111	31.8	10.3	15.2
octanal	35.4	35.3	7.9	35.7	16.2
methanol	58.2	70.5	98.1	55.1	61.5
ethanol	6,120	1,915	330	69.3	347
i-propanol	202	510	48.0	20.7	16.5
propanol	28.6	132	14.5	3.0	9.3
acetone	517	649	205	112	69.9
2-butanone	165	175	21.1	33.4	3.0
benzene	62.2	58.6	2.8	88.3	0.9
toluene	38.0	72.9	15.2	23.8	5.0
ethylbenzene	24.5	78.0	2.2	5.4	0.6
m,p-xylene	44.8	131	5.2	5.9	1.6
o-xylene	22.7	112	4.9	4.0	0.8
dichloromethane	45.0	3.0	20.1	106	17.5
chloroform	4.5	27.4	18.6	9.2	3.7
1,1,1-trichloroethane	6.5	2.6	2.2	1.1	1.5
Sum Sulphurs	223	16,026	264	114	67
Sum Aldehydes	1,588	3,230	817	288	76
Sum others	7,339	3,938	787	537	539
TOTAL (ppb)	**9,150**	**23,194**	**1,868**	**938**	**681**

Plant E	Raw	Drier	Factory air	Drier	Non	Cookers
nonpolar column	materials			Biofilter (out)	condensables	insp. gantry
10-Nov-97						
component (ppb)	concentration					
hydrogen sulphide	217	120	58.1	9.9	114,895	329
carbonylsulphide	9.9	2,384	208	8.0	9,062	29.5
sulphurdioxide	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
methylmercaptan	24.1	41.8	170	12.0	24,661	51.8
dimethylsulphide	0.9	161	8.5	1.5	174	0.4
carbondisulphide	13.1	505	20.9	52.8	427	7.2
ethylmercaptan	<0.1	<0.1	1.6	<0.1	50.9	<0.1
i-propylmercaptan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
propylmercaptan	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
dimethyldisulphide	1.4	26.9	4.6	0.2	56.0	0.4
dimethyltrisulphide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
acetaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
propenal	5.1	<0.1	0.8	0.3	22.1	3.8
2-butenal	28.5	46.4	2.9	0.4	43.2	1.6
butanal	4.2	19.8	5.1	<0.1	39.6	1.3
2-methylpropanal	3.3	76.9	75.2	2.3	2,331	12.9
2-methylpropenal	4.0	45.3	2.5	1.4	21.7	2.3
2-methylbutanal	5.5	35.2	111	2.7	4,244	19.8
3-methylbutanal	11.6	128	161	1.3	11,035	39.2
pentanal	24.5	107	113	23.3	351	30.3
hexanal	17.5	143	42.4	5.9	218	9.5
heptanal	16.5	123	11.2	4.1	129	7.0
methanol	30.7	1,078	61.9	36.8	648	51.7
ethanol	112	681	1,379	54.6	3,787	253
i-propanol	14.5	306	17.7	19.2	213	15.6
propanol	2.7	64.4	7.9	1.3	110	5.4
t-butanol	5.6	979	3.2	5.3	7.7	1.4
i-butanol	1.7	90.3	1.6	0.8	3.3	1.4
2-butanol	1.3	44.2	3.0	0.3	11.9	0.8
butanol	5.9	66.0	87.7	24.4	12.7	4.3
3-methylbutanol	1.3	80.2	6.0	3.7	27.8	1.8
acetone	124	2,125	286	79.6	1,058	106
2-butanone	6.6	289	28.7	0.1	85.1	4.4
3-buten-2-one	5.2	104	3.6	5.6	13.8	3.9
2,3-butanedione	5.8	68.9	12.9	3.5	149	6.2
methylisobutylketone	7.5	190	14.2	6.3	53.5	13.8
ethylacetate	8.0	53.5	2.6	4.0	11.0	2.0
benzene	1.0	21.3	3.3	9.3	274	0.8
toluene	16.2	196	21.8	128	43.6	17.3
ethylbenzene	1.9	34.3	1.3	3.7	4.9	1.0
m,p-xylene	5.7	32.0	3.0	11.6	9.7	2.5
o-xylene	2.5	14.4	1.2	3.5	4.6	1.1
dichloromethane	15.0	37.8	14.0	56.5	63.9	5.0
chloroform	2.6	45.6	4.7	7.0	15.2	1.1
1,1,1-trichloroethane	3.2	3.8	1.3	7.8	10.5	1.2
trichloroethylene	4.9	44.3	2.6	4.5	120	1.5
tetrachloroethylene	1.1	53.3	0.2	5.0	1.4	0.4
methylcyclopentane	0.5	14.2	1.7	3.0	1.5	1.4
methylcyclohexane	1.1	50.9	6.8	12.5	5.4	4.4
cyclohexane	2.3	1.7	7.9	20.0	0.7	4.8
hexene	2.6	1.9	9.0	22.8	0.8	5.5
heptene	2.2	1.7	7.7	19.6	0.7	4.7
octene	1.9	1.5	6.8	17.1	0.6	4.1
nonene	1.7	1.3	6.0	15.2	0.5	3.7
Sum Sulphurs	267	3,239	472	84	149,325	418
Sum Aldehydes	121	726	525	42	18,432	128
Sum others	399	6,776	2,015	592	6,751	532
TOTAL ppb	**787**	**10,741**	**3,012**	**719**	**174,508**	**1,078**

Plant E	Raw	Drier	Factory air	Drier	Non	Cookers
polar column	materials			Biofilter (out)	condensables	insp. gantry
10-Nov-97						
component (ppb)	concentration					
hydrogen sulphide	100	144	76.6	12.0	35,615	262
carbonylsulphide	4.2	146	121	5.9	4,458	28.5
sulphurdioxide	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
methylmercaptan	21.9	92.7	49.6	2.6	10,198	42.9
dimethylsulphide	0.0	3.4	1.8	1.1	61.7	0.0
carbondisulphide	0.0	1.7	0.2	0.1	135	0.0
dimethyldisulphide	0.6	1.6	2.5	0.2	27.0	1.4
dimethyltrisulphide	1.8	1.8	5.5	0.2	112	8.7
acetaldehyde	6.0	126	21.0	26.3	405	4.7
propenal	2.6	5.2	7.4	3.5	33.0	12.0
propanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
butanal	0.5	1.5	4.6	0.5	23.2	3.5
2-methylpropanal	1.7	1.7	48.5	1.1	1,740	16.7
2-methylpropenal	1.0	1.1	1.2	0.7	9.8	2.1
2-methylbutanal	1.3	0.7	25.3	0.2	1,898	33.6
3-methylbutanal	2.6	2.9	56.0	2.0	5,704	37.2
pentanal	1.7	1.7	9.6	1.5	50.3	3.7
hexanal	7.8	5.8	18.2	5.6	221	14.1
heptanal	7.3	5.4	11.4	3.8	160	11.3
octanal	11.0	9.1	15.8	4.1	234	24.9
methanol	42.1	11.8	62.8	39.6	294	68.8
ethanol	88.7	3,527	877	37.3	2,151	160
i-propanol	10.4	26.5	14.6	5.9	106	17.0
propanol	3.5	4.8	7.4	0.7	156	24.6
acetone	31.1	422	141	53.1	346	48.8
2-butanone	1.4	9.0	16.8	1.2	43.1	4.8
benzene	0.2	0.8	1.2	6.5	61.1	1.7
toluene	2.6	3.1	2.4	66.3	6.9	4.5
ethylbenzene	0.5	2.0	0.5	3.8	3.2	0.7
m,p-xylene	1.8	1.7	1.3	12.8	10.0	2.0
o-xylene	1.3	1.4	1.1	4.2	35.7	1.5
dichloromethane	0.8	0.6	0.7	0.7	6.4	0.6
chloroform	0.6	1.0	1.7	1.2	4.9	1.8
1,1,1-trichloroethane	0.5	0.4	0.4	4.5	2.9	1.2
Sum Sulphurs	129	391	257	22	50,606	343
Sum Aldehydes	44	161	219	49	10,478	164
Sum others	185	4,012	1,129	238	3,227	338
TOTAL ppb	**358**	**4,565**	**1,605**	**310**	**64,311**	**846**

CH2M HILL

APPENDIX 3

3a CHEMICAL ODOUR UNITS FOR IDENTIFIED COMPOUNDS

3b CHEMICAL ODOUR DISTRIBUTION FOR INDIVIDUAL PLANTS

Plant A	Threshold	Blood drier	Biofilter	Biofilter	Kill floor
nonpolar column	(ppb)	Outlet	outlet	inlet	air vent
6-Nov-97					
component (ppb)			Chemical Odour Units		
hydrogen sulphide	0.25				
carbonylsulphide	100	0.3	0.8	0.8	0.1
sulphurdioxide	9				
methylmercaptan	0.35	168	4.4	1,299	67.6
dimethylsulphide	0.97	15.5	1.1	12.0	0.3
carbondisulphide	20	0.4	1.4	1.1	0.2
ethylmercaptan	1				0.3
i-propylmercaptan	1				
propylmercaptan	1				
dimethyldisulphide	1.76	10.0	1.2	19.8	0.8
dimethyltrisulphide	2.0	0.2	0.2	7.8	0.5
acetaldehyde	3	7.5	0.8	53.6	5.7
propenal	1	65.3	12.9	5.2	5.2
2-butenal	1	10.2	1.5	10.2	1.2
butanal	1	7.3	2.1	5.8	1.5
2-methylpropanal	0.54	179	5.1	269	8.0
2-methylpropenal	0.6	19.4	6.4	30.4	4.2
2-methylbutanal	0.3	273	4.9	511	11.6
3-methylbutanal	0.24	644	8.8	369	16.1
pentanal	0.5				
hexanal	5.9	5.8	9.1	6.1	1.4
heptanal	0.7	35.4	49.8	40.0	11.2
methanol	1000	0.4	0.0	0.3	0.1
ethanol	1750	0.7	0.0	1.0	0.9
i-propanol	500	0.2	0.0	0.2	0.0
propanol	600	0.1	0.0	0.1	0.0
t-butanol	1270	0.0	0.0	0.0	0.0
i-butanol	80	0.0	0.0	0.1	0.0
2-butanol	50	0.1	0.0	0.1	0.0
butanol	40	0.8	0.2	0.6	0.1
3-methylbutanol	80	0.1	0.0	0.1	0.0
acetone	420	0.9	0.2	0.9	0.3
2-butanone	9	2.1	0.4	2.9	0.3
3-buten-2-one	20	0.2	0.2	0.2	0.1
2,3-butanedione	20	0.0	0.0	0.4	0.3
methylisobutylketone	100	0.1	0.1	0.2	0.1
ethylacetate	710	0.0	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0
chloroform	150	0.0	0.0	0.0	0.1
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0
trichloroethylene	150	0.0	0.0	0.0	0.0
tetrachloroethylene	150	0.0	0.0	0.0	0.0
methylcyclopentane	150	0.0	0.0	0.1	0.0
methylcyclohexane	150	0.0	0.0	0.0	0.0
cyclohexane	150	0.0	0.0	0.0	0.0
hexene	25	0.0	1.1	0.2	0.0
Thiophene	25		0.1		
octene	25		0.9		
Sum Sulphurs	Sum Sulphurs	194	9	1,341	70
Sum Aldehydes	Sum Aldehydes	1247	101	1300	66
Sum others	Sum others	6	2	8	2
TOTAL ppb	**COU**	**1,447**	**113**	**2,648**	**138**
	OU	**4,790**	**564**	**7,640**	**912**
	ratio (OU/COU)	3.3	5.0	2.9	6.6

Plant A	Threshold	**Blood drier**	**Biofilter**	**Biofilter**	**Kill floor**
polar column	(ppb)	**Outlet**	**outlet**	**inlet**	**air vent**
6-Nov-97					
component (ppb)					
hydrogen sulphide	0.25	31.6	25.7	20.7	6.1
carbonylsulphide	100	0.2	0.5	0.5	0.0
sulphurdioxide	9				
methylmercaptan	0.35	5.1	17.5	542.3	19.0
dimethylsulphide	0.97	0.4	0.3	0.5	0.2
carbondisulphide	20	0.0	0.0	0.0	0.0
dimethyldisulphide	1.76	9.2	6.6	7.0	0.4
dimethyltrisulphide	2.0	4.3	2.0	17.0	1.3
acetaldehyde	3	29.4	0.7	6.1	0.6
propenal	1	43.9	7.0	23.9	3.3
propanal	1	13.0	2.5	8.0	1.1
butanal	1	8	2	7	1
2-methylpropanal	0.54	181	6	197	3
2-methylpropenal	0.6	24	8	23	2
2-methylbutanal	0.3	137	4	218	2
3-methylbutanal	0.24	342	8	583	12
pentanal	0.5	36	9	27	4
hexanal	5.9	7	6	3	1
heptanal	0.7	66	50	28	8
octanal	0.5	38	25	39	18
methanol	1000	0.2	0.1	0.2	0.1
ethanol	1750	0.9	0.0	0.8	0.7
i-propanol	500	0.2	0.0	0.2	0.0
propanol	600	0.0	0.0	0.1	0.0
acetone	420	0.7	0.2	0.6	0.1
2-butanone	9	2.5	0.4	2.2	0.2
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0
chloroform	150	0.0	0.0	0.0	0.1
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0
Sum Sulphurs	Sum Sulphurs	51	53	588	27
Sum Aldehydes	Sum Aldehydes	924	128	1,162	57
Sum others	Sum others	5	1	4	1
TOTAL ppb	**COU**	**980**	**182**	**1,754**	**85**
	OU	**4,790**	**564**	**7,640**	**912**
	ratio (OU/COU)	4.9	3.1	4.4	10.7

Plant A	Threshold	**Biofilter**	**Biofilter**	**Cooker room**	**Kill floor**
nonpolar column	(ppb)	**outlet**	**inlet**	**exhaust**	**air vent**
18-Dec-97					
component (ppb)					
hydrogen sulphide	0.25				
carbonylsulphide	100	0.8	0.6	0.1	0.0
sulphurdioxide	9	0.0		0.0	
methylmercaptan	0.35	39.7		228	15.4
dimethylsulphide	0.97	10.0	2.5	1.3	0.0
carbondisulphide	20	1.1	0.8	0.1	0.1
ethylmercaptan	1	0.7		0.3	
i-propylmercaptan	1			0.0	
propylmercaptan	1				
dimethyldisulphide	1.76	10.2	6.1	0.5	0.2
dimethyltrisulphide	2.0	0.2			
acetaldehyde	3	4.5	3.7	22.1	1.8
propenal	1	6.7	16.5	6.3	1.6
2-butenal	1	0.7	2.2	10.8	0.1
butanal	1	2.4	0.5	5.0	0.7
2-methylpropanal	0.54	7.6	95.7	143	2.4
2-methylpropenal	0.6	12.6	33.4	5.7	2.0
2-methylbutanal	0.3	1.9	37.0	50.6	0.7
3-methylbutanal	0.24	5.5	223	251	2.9
pentanal	0.5	23.2	8.5	10.3	4.2
hexanal	5.9	0.7	0.6	1.6	0.4
heptanal	0.7	1.3	9.4	8.0	1.3
methanol	1000	0.5	0.6	0.4	0.1
ethanol	1750	0.2	0.3	0.1	0.0
i-propanol	500	0.2	0.3	0.0	0.0
propanol	600	0.1	0.1	0.0	0.0
t-butanol	1270				
i-butanol	80				
2-butanol	50			0.1	
butanol	40				
3-methylbutanol	80	0.0	0.0	0.0	
acetone	420	0.4	1.3	0.6	0.1
2-butanone	9	25.2	3.7	1.5	0.2
3-buten-2-one	20	0.9	0.6	0.2	0.1
2,3-butanedione	20	0.1	0.3	2.0	0.1
methylisobutylketone	100	0.0	0.3	0.0	0.0
ethylacetate	710	0.1	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.6	0.0	0.0	0.0
chloroform	150	0.1	0.0	0.0	0.0
1,1,1-trichloroethane	150	0.2	0.0	0.0	0.0
trichloroethylene	150	0.3		0.0	0.0
tetrachloroethylene	150	0.0			
methylcyclopentane	150	0.1	0.0	0.0	0.0
methylcyclohexane	150	0.0			
cyclohexane	150				
hexene	25				
Thiophene	25				
octene	25				
Sum Sulphurs	Sum Sulphurs	62	10	230	16
Sum Aldehydes	Sum Aldehydes	67	431	514	18
Sum others	Sum others	29	8	5	1
TOTAL ppb	**COU**	**158**	**449**	**749**	**34**
	OU	**8,220**	**12,100**	**7,530**	**452**
	ratio (OU/COU)	52.0	27.0	10.1	13.1

Plant A	Threshold	**Biofilter**	**Biofilter**	**Cooker room**	**Kill floor**
polar column	(ppb)	**outlet**	**inlet**	**exhaust**	**air vent**
18-Dec-97					
component (ppb)					
hydrogen sulphide	0.25	16.2	11.4		
carbonylsulphide	100	0.4	0.3	0.1	0.1
sulphurdioxide	9			0.0	
methylmercaptan	0.35	121	30.5	73.7	13.1
dimethylsulphide	0.97	0.4	0.1	0.1	0.0
carbondisulphide	20	0.0	0.0	0.0	
dimethyldisulphide	1.76	10.2	6.4	4.0	0.4
dimethyltrisulphide	2.0	0.9	1.2	1.3	0.1
acetaldehyde	3	3.0	34.3	1.6	0.5
propenal	1	3.3	10.1	6.8	2.3
propanal	1	11.8	34.7	13.7	1.1
butanal	1	18.4	5.6	2.8	0.4
2-methylpropanal	0.54	3.8	123	85.1	1.5
2-methylpropenal	0.6	3.0	19.8	5.4	1.4
2-methylbutanal	0.3	2.8	38.2	126	2.5
3-methylbutanal	0.24	12.5	266	495	13.1
pentanal	0.5	13.5	17.0	44.8	5.5
hexanal	5.9	0.9	0.5	0.7	0.1
heptanal	0.7	22.6	17.0	26.8	4.2
octanal	0.5	15.5	23.2	28.4	5.6
methanol	1000	0.2	0.2	0.1	0.0
ethanol	1750	0.0	0.1	0.0	0.0
i-propanol	500	0.0	0.1	0.0	0.0
propanol	600	0.0	0.0	0.0	0.0
acetone	420	0.1	0.9	0.3	0.0
2-butanone	9	4.8	6.3	15.0	7.0
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0
chloroform	150	0.0	0.0	0.0	0.0
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0
Sum Sulphurs	Sum Sulphurs	149	50	79	14
Sum Aldehydes	Sum Aldehydes	111	590	837	38
Sum others	Sum others	5	8	15	7
TOTAL ppb	**COU**	**265**	**647**	**932**	**59**
	OU	**8,220**	**12,100**	**7,530**	**452**
	ratio (OU/COU)	31.0	18.7	8.1	7.7

Plant B	Threshold	Cooker Gas	Press Air	Blood Drier	DAF Tank	Tallow Boiling
nonpolar column	(ppb)			Outlet		Tank
19-Nov-97						
component (ppb)		Chemical Odour Units				
hydrogen sulphide	0.25		867	560	216.3	1,042
carbonylsulphide	100	12.0	2.3	0.1	0.1	1.2
sulphurdioxide	9				0.1	
methylmercaptan	0.35	10,259	11,261	84.3	116.1	8,739
dimethylsulphide	0.97	305	20.0	0.2	0.5	10.6
carbondisulphide	20	5.9	3.6	0.2	0.3	0.3
ethylmercaptan	1	12.3	47.2	0.2	0.3	23.4
i-propylmercaptan	1					
propylmercaptan	1					
dimethyldisulphide	1.76	164	20.9	0.9	0.7	93.3
dimethyltrisulphide	2.0					
acetaldehyde	3	230	280	23.5	7.7	
propenal	1	44.8	62.2	4.8	4.7	217
2-butenal	1	35.8	53.7	1.6	2.9	142
butanal	1	72.1	18.1	2.0	0.6	247
2-methylpropanal	0.54	10,298	2,708	10.0	9.4	4,153
2-methylpropenal	0.6	68.8	26.1	5.0	3.7	124
2-methylbutanal	0.3	18,886	4,936	27.2	28.5	13,393
3-methylbutanal	0.24	48,113	10,170	28.8	73.5	37,750
pentanal	0.5	9,901	488	48.2	43.0	7,850
hexanal	5.9	32.3	16.2	2.1	0.9	167
heptanal	0.7	52.9	30.2	3.0	18.8	327
methanol	1000	1.9	1.3	0.1	0.1	0.1
ethanol	1750	1.0	6.5	0.1	0.2	0.1
i-propanol	500	1.1	1.1	0.0	0.0	0.2
propanol	600	0.4	0.2	0.0	0.0	0.0
t-butanol	1270	0.0	0.0	0.0	0.0	0.0
i-butanol	80	0.2	0.2	0.2	0.1	0.1
2-butanol	50	0.1	0.2	0.0	0.0	0.2
butanol	40	1.7	2.0	0.1	0.1	0.8
3-methylbutanol	80	1.1	0.3	0.0	0.0	1.4
acetone	420	18.9	12.6	0.4	1.9	13.7
2-butanone	9	29.5	33.0	0.5	0.4	39.5
3-buten-2-one	20	3.4	0.7	0.2	0.1	4.3
2,3-butanedione	20	39.5	10.7	0.6	0.6	22.1
methylisobutylketone	100	0.6	0.4	0.3	0.1	0.7
ethylacetate	710	0.0	0.0	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.5	0.2	0.1	0.1	0.1
chloroform	150	0.1	0.1	0.0	0.0	0.0
1,1,1-trichloroethane	150	0.1	0.3	0.0	0.0	0.0
trichloroethylene	150	0.2	0.1	0.0	0.0	0.6
tetrachloroethylene	150	0.1	0.0		0.0	
methylcyclopentane	150					
methylcyclohexane	150					
cyclohexane	150					
hexene	25					
Thiophene	25					
octene	25					
Sum Sulphurs	Sum Sulphurs	10,758	12,222	646	334	9,910
Sum Aldehydes	Sum Aldehydes	87,734	18,789	156	194	64,371
Sum others	Sum others	100	70	3	4	84
TOTAL ppb	**COU**	**98,593**	**31,081**	**804**	**532**	**74,364**
	OU	**48,600**	**460,000**	**15,000**	**9,030**	**121,000**
	ratio (OU/COU)	0.5	14.8	18.6	17.0	1.6

Plant B	Threshold	Cooker Gas	Press Air	Blood Drier	DAF Tank	Tallow Boiling
polar column	(ppb)			Outlet		Tank
19-Nov-97						
component (ppb)		Chemical Odour Units				
hydrogen sulphide	0.25	5.4	3.6			16.5
carbonylsulphide	100	1.0	0.3			0.6
sulphurdioxide	9	0.0				0.0
methylmercaptan	0.35	36.2	17.9			30.3
dimethylsulphide	0.97	14.7	3.7			2.9
carbondisulphide	20	0.0	0.0			0.0
dimethyldisulphide	1.76	30.6	18.9			122
dimethyltrisulphide	2.0	15.0	19.6			69.1
acetaldehyde	3	955	139			161
propenal	1					
propanal	1	222	270			590
butanal	1	40.9	25.5			145
2-methylpropanal	0.54	1,230	805			1,602
2-methylpropenal	0.6	24.7	13.1			50.5
2-methylbutanal	0.3	2,629	1,113			2,548
3-methylbutanal	0.24	4,779	2,334			3,027
pentanal	0.5	724	89.3			1,204
hexanal	5.9	15.4	10.3			107
heptanal	0.7	74.0	71.2			439
octanal	0.5	29.1	29.3			427
methanol	1000	0.6	0.2			0.4
ethanol	1750	0.2	0.0			0.1
i-propanol	500	0.3	0.2			0.1
propanol	600	0.1	0.0			0.1
acetone	420	5.0	1.5			4.2
2-butanone	9	12.7	30.0			24.6
benzene	6000	0.0	0.0			0.0
toluene	5000	0.0	0.0			0.0
ethylbenzene	10000	0.0	0.0			0.0
m,p-xylene	10000	0.0	0.0			0.0
o-xylene	10000	0.0	0.0			0.0
dichloromethane	150	0.1	0.1			0.0
chloroform	150	0.0	0.1			0.0
1,1,1-trichloroethane	150	0.0	0.0			0.0
Sum Sulphurs	Sum Sulphurs	103	64	0	0	242
Sum Aldehydes	Sum Aldehydes	10,723	4,900	0	0	10,299
Sum others	Sum others	19	32	0	0	30
TOTAL ppb	**COU**	**10,846**	**4,996**	**0**	**0**	**10,570**
	OU	**48,600**	**460,000**	**15,000**	**9,030**	**121,000**
	ratio (OU/COU)	4.5	92.1			11.4

Plant B	Threshold	Cooker Gas	Press Air	Blood Drier	Tallow Boiling
nonpolar column	(ppb)			Outlet	Tank
19-Dec-97					
component (ppb)		Chemical Odour Units			
hydrogen sulphide	0.25			1,558	
carbonylsulphide	100	0.8	1.8	0.6	0.7
sulphurdioxide	9			0.5	
methylmercaptan	0.35	294	5,555	1,927	1,535
dimethylsulphide	0.97	30.4	31.7	1.5	23.4
carbondisulphide	20	2.4	1.3	0.5	0.7
ethylmercaptan	1	20.2			43.3
i-propylmercaptan	1				
propylmercaptan	1	0.9		0.5	
dimethyldisulphide	1.76	98.4	11.1	7.4	16.3
dimethyltrisulphide	2.0				
acetaldehyde	3		6,400		
propenal	1	117	27.0	161	181
2-butenal	1		360	19.3	55.8
butanal	1	79.2	40.5	20.9	78.6
2-methylpropanal	0.54	2,265	3,007	97.8	4,702
2-methylpropenal	0.6	115	23.5	14.1	44.2
2-methylbutanal	0.3	2,434	1,917	55.3	1,854
3-methylbutanal	0.24	7,938	3,583	177	5,921
pentanal	0.5		131	96.6	1,255
hexanal	5.9	9.3	4.4	4.9	59.7
heptanal	0.7	77.0	14.8	68.2	262
methanol	1000	3.8	3.5	0.3	0.4
ethanol	1750	0.5	0.1	0.0	0.1
i-propanol	500	0.4	0.2	0.1	0.9
propanol	600	0.5	0.1	0.0	0.0
t-butanol	1270	0.1	0.0	0.0	0.0
i-butanol	80	1.0	0.0	0.0	0.1
2-butanol	50	0.9	0.1	0.0	0.1
butanol	40			0.0	
3-methylbutanol	80		0.1	0.1	0.1
acetone	420	5.7	4.0	1.3	9.2
2-butanone	9	18.5	23.6	2.6	19.1
3-buten-2-one	20	4.3	0.9	0.4	3.8
2,3-butanedione	20	38.5	11.5	1.1	24.7
methylisobutylketone	100	0.2	0.0	0.0	0.0
ethylacetate	710	0.0	0.0	0.0	0.1
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.1	0.0	0.0	0.0
chloroform	150	0.0	0.0	0.0	0.0
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0
trichloroethylene	150	0.1	0.0	0.0	
tetrachloroethylene	150	0.0			
methylcyclopentane	150				0.0
methylcyclohexane	150	0.0			0.0
cyclohexane	150	0.8			
hexene	25				
Thiophene	25				
octene	25				
Sum Sulphurs	Sum Sulphurs	447	5,601	3,496	1,620
Sum Aldehydes	Sum Aldehydes	13034	15508	716	14414
Sum others	Sum others	76	44	6	59
TOTAL ppb	**COU**	**13,557**	**21,153**	**4,217**	**16,092**
	OU	**44,900**	**240,000**	**12,400**	**23,400**
	ratio (OU/COU)	3.3	11.3	2.9	1.5

Plant B	Threshold	Cooker Gas	Press Air	Blood Drier	Tallow Boiling
polar column	(ppb)			Outlet	Tank
19-Dec-97					
component (ppb)		Chemical Odour Units			
hydrogen sulphide	0.25		1,325	221	213
carbonylsulphide	100	0.8	0.7	0.0	0.9
sulphurdioxide	9				
methylmercaptan	0.35	1,050	10,946	323	12,484
dimethylsulphide	0.97	5.5	7.9	0.8	17.4
carbondisulphide	20	0.1	0.0	0.0	0.0
dimethyldisulphide	1.76	185	121	6.0	92.3
dimethyltrisulphide	2.0	20.1	10.0	0.9	9.0
acetaldehyde	3	1,276	1,455	136	112
propenal	1				
propanal	1	42.0	125		217
butanal	1	32.9	178	11.7	76.3
2-methylpropanal	0.54	478	1,232	4.6	1,543
2-methylpropenal	0.6	12.1	10.5	1.4	8.5
2-methylbutanal	0.3	1,306	3,162	6.0	2,223
3-methylbutanal	0.24	1,436	3,999	11.3	3,930
pentanal	0.5	101	112	3.7	196
hexanal	5.9	1.3	1.9	0.2	14.2
heptanal	0.7	55.2	40.4	2.8	53.2
octanal	0.5	41.0	51.2	1.2	5.2
methanol	1000	0.3	1.2	0.1	0.5
ethanol	1750	4.5	12.5	0.4	4.2
i-propanol	500	0.3	0.5	0.0	0.3
propanol	600	0.5	1.9	0.1	0.6
acetone	420	1.4	1.5	0.1	2.0
2-butanone	9	13.4	31.0	1.6	24.5
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0
chloroform	150	0.1	0.1	0.0	0.1
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0
Sum Sulphurs	Sum Sulphurs	1,261	12,410	552	12,816
Sum Aldehydes	Sum Aldehydes	4,782	10,367	179	8,379
Sum others	Sum others	21	49	2	32
TOTAL ppb	**COU**	**6,064**	**22,826**	**733**	**21,227**
	OU	**44,900**	**240,000**	**12,400**	**23,400**
	ratio (OU/COU)	7.4	10.5	16.9	1.1

Plant C	Threshold	RP 2	Scrubber	RP 3	Scrubber
nonpolar column	(ppb)		Outlet		Inlet
26-Nov-97					
component (ppb)		Chemical Odour Units			
hydrogen sulphide	0.25	0.2	406	218	140
carbonylsulphide	100	0.1	0.6	0.1	1.1
sulphurdioxide	9				
methylmercaptan	0.35	521	15,394	507	14,024
dimethylsulphide	0.97	1.5	47.3	3.0	36.1
carbondisulphide	20	0.4	1.7	0.1	3.3
ethylmercaptan	1				
i-propylmercaptan	1				1.7
propylmercaptan	1				
dimethyldisulphide	1.76	5.3	95.6	5.1	131
dimethyltrisulphide	2.0	0.0	0.2	0.2	1.3
acetaldehyde	3	1.0	69.1	3.2	292
propenal	1	1.9	5.1	3.2	7
2-butenal	1	2.0	1.8	0.5	10
butanal	1	3.8	32.4	1.5	38.5
2-methylpropanal	0.54	55.6	1,653	5.7	2,155
2-methylpropenal	0.6	3.0	12.3	1.8	8.7
2-methylbutanal	0.3	180	5,660	7.3	4,859
3-methylbutanal	0.24	213	7,288	17.1	7,890
pentanal	0.5	1.8	26	1.6	96
hexanal	5.9	1.8	17.9	0.7	39.3
heptanal	0.7	0.03	40.5	10.1	133.3
acetic acid	9.0				
methanol	1000	0.1	1.1	0.1	1.2
ethanol	1750	0.3	6.5	0.4	6.7
i-propanol	500	0.0	0.4	0.0	0.5
propanol	600	0.1	1.1	0.0	1.1
t-butanol	1270	0.0	0.0	0.0	0.0
i-butanol	80	0.1	0.2	0.0	0.7
2-butanol	50	0.3	1.3	0.1	1.6
butanol	40	0.3	22.4	0.4	24.6
3-methylbutanol	80	0.0	0.7	0.0	0.8
acetone	420	0.2	3.4	0.1	3.1
2-butanone	9	2.2	21.6	1.0	25.6
3-buten-2-one	20	0.1	0.0	0.0	0.0
2,3-butanedione	20	0.5	5.5	0.2	0.0
methylisobutylketone	100	0.1	0.7	0.1	0.6
ethylacetate	710	0.0	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.1	0.0	0.0
chloroform	150	0.0	0.1	0.0	0.1
1,1,1-trichloroethane	150	0.1	0.0	0.0	0.0
trichloroethylene	150	0.0	0.0	0.0	0.1
tetrachloroethylene	150	0.0	0.0	0.0	0.0
methylcyclopentane	150	0.0	0.0	0.0	0.0
methylcyclohexane	150	0.0	0.0	0.0	0.0
cyclohexane	150	0.0	0.0	0.0	0.1
hexene	25	0.0	0.0	0.0	0.0
Sum Sulphurs	Sum Sulphurs	528	15,946	733	14,339
Sum Aldehydes	Sum Aldehydes	464	14807	53	15529
Sum others	Sum others	4	65	3	67
TOTAL ppb	**COU**	**997**	**30,818**	**788**	**29,935**
	OU	**8,960**	**203,000**	**7,960**	**161,000**
	ratio (OU/COU)	9.0	6.6	10.1	5.4

Plant C	Threshold	RP 2	Scrubber	RP 3	Scrubber
polar column	(ppb)		Outlet		Inlet
26-Nov-97					
component (ppb)		Chemical Odour Units			
hydrogen sulphide	0.25		1,325	221	213
carbonylsulphide	100	0.1	0.7	0.0	0.9
sulphurdioxide	9				
methylmercaptan	0.35	105	10,946	323	12,484
dimethylsulphide	0.97	0.6	7.9	0.8	17.4
carbondisulphide	20	0.0	0.0	0.0	0.0
dimethyldisulphide	1.76	18.5	121	6.0	92.3
dimethyltrisulphide	2.0	2.0	10.0	0.9	9.0
acetaldehyde	3	5.6	903	14.2	1,318
propenal	1				
propanal	1	4.2	125		217
butanal	1	3.3	178	11.7	76.3
2-methylpropanal	0.54	47.8	1,232	4.6	1,543
2-methylpropenal	0.6	1.2	10.5	1.4	8.5
2-methylbutanal	0.3	131	3,162	6.0	2,223
3-methylbutanal	0.24	144	3,999	11.3	3,930
pentanal	0.5	10.1	112	3.7	196
hexanal	5.9	0.1	1.9	0.2	14.2
heptanal	0.7	5.5	40.4	2.8	53.2
octanal	0.5	4.1	51.2	1.2	5.2
methanol	1000	0.0	1.2	0.1	0.5
ethanol	1750	0.4	12.5	0.4	4.2
i-propanol	500	0.0	0.5	0.0	0.3
propanol	600	0.1	1.9	0.1	0.6
acetone	420	0.1	1.5	0.1	2.0
2-butanone	9	1.3	31.0	1.6	24.5
benzene	6000	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0
chloroform	150	0.0	0.1	0.0	0.1
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0
Sum Sulphurs	Sum Sulphurs	126	12,410	552	12,817
Sum Aldehydes	Sum Aldehydes	356	9,816	57	9,584
Sum others	Sum others	2	49	2	32
TOTAL ppb	**COU**	**484**	**22,275**	**611**	**22,433**
	OU	**8,960**	**203,000**	**7,960**	**161,000**
	ratio (OU/COU)	18.5	9.1	13.0	7.2

Plant C	W Threshold	RP 3	Scrubber	RP 3	RP 1	Scrubber
nonpolar column	(ppb)	before ozone	Outlet	after ozone	stack	Inlet
4-Mar-98						
component (ppb)		Chemical Odour Units				
hydrogen sulphide	0.25	91.4	16,905	10.6		43,387
carbonylsulphide	100	0.0	0.8	0.0	0.2	2.9
sulphurdioxide	9	0.0		0.0	222	
methylmercaptan	0.35	271	8,869	108		25,370
dimethylsulphide	0.97	0.4	14.5	0.2	0.4	18.1
carbondisulphide	20	0.1	0.0	0.0	0.0	0.4
ethylmercaptan	1	0.1	5.5		0.1	2.7
i-propylmercaptan	1					
propylmercaptan	1					
dimethyldisulphide	1.76	0.7	13.3	0.7	0.5	15.8
dimethyltrisulphide	2.0					
acetaldehyde	3	1.1	8.0			
propenal	1					
2-butenal	1					
butanal	1	0.4	12.3	0.2	1.0	21.8
2-methylpropanal	0.54	1.9	749	2.4	119	1,416
2-methylpropenal	0.6	0.3	3.5	0.3	1.8	3.5
2-methylbutanal	0.3	2.1	1,109	2.5	99.3	1,029
3-methylbutanal	0.24	4.5	7,084	2.8	300	6,522
pentanal	0.5					
hexanal	5.9	0.3	5.0	0.9	0.4	2.2
heptanal	0.7		5.7			
acetic acid	9.0					
methanol	1000	0.0	0.0	0.0	0.1	1.6
ethanol	1750	0.2	3.3	0.2	0.2	3.1
i-propanol	500	0.0	0.2	0.0	0.0	0.3
propanol	600	0.1	1.8	0.1	0.4	2.4
t-butanol	1270	0.0	0.0	0.0	0.0	0.0
i-butanol	80	0.0	0.4	0.0	0.0	
2-butanol	50	0.0	1.0	0.1	0.1	0.8
butanol	40	0.0	0.1	0.0	0.1	0.1
3-methylbutanol	80		0.1	0.0	0.0	
acetone	420	0.1	2.0	0.0	0.6	2.3
2-butanone	9	0.2	11.7	0.2	0.9	20.7
3-buten-2-one	20	0.0	0.0	0.0	0.0	
2,3-butanedione	20	0.1	9.0	0.2	0.2	11.0
methylisobutylketone	100	0.1	0.2	0.2	0.1	0.1
ethylacetate	710	0.0	0.1	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	
m,p-xylene	10000	0.0	0.0	0.0	0.0	
o-xylene	10000	0.0	0.0	0.0	0.0	
dichloromethane	150	0.0	0.0	0.0	0.0	0.0
chloroform	150	0.0	0.1	0.0	0.0	0.1
1,1,1-trichloroethane	150		0.0			
trichloroethylene	150	0.0	0.0	0.0	0.0	0.0
tetrachloroethylene	150					
methylcyclopentane	150		0.0		0.0	0.0
methylcyclohexane	150				0.0	
cyclohexane	150	0.0		0.0		0.0
hexene	25	0.0	0.1	0.1	0.3	0.2
Sum Sulphurs	Sum Sulphurs	364	25,807	120	223	68,797
Sum Aldehydes	Sum Aldehydes	11	8977	9	521	8995
Sum others	Sum others	1	30	1	3	43
TOTAL ppb	**COU**	**375**	**34,814**	**130**	**747**	**77,834**
	OU	**21,930**	**200,000**	**15,680**	**13,400**	**335,000**
ODU	ratio (OU/COU	58.5	5.7	120.6	17.9	4.3

Volatile organic components from Meat processing plant

Plant D	Threshold	Blood Tank	Waste water	Incinerator	Hammermill	Tallow Day
nonpolar column	(ppb)		Shaker screen		room	Tank
15-Nov-97						
component (ppb)		Chemical Odour Units				
hydrogen sulphide	0.25	386,391	1,130	668,133	1,573	400
carbonylsulphide	100	2	0	312	0	0
sulphurdioxide	9					
methylmercaptan	0.35	151,962	1,489	1,226,896	912	356
dimethylsulphide	0.97	3,469	106	4,036	1.2	0.7
carbondisulphide	20	16.6	0.8	16.2	0.7	0.5
ethylmercaptan	1					
i-propylmercaptan	1	21.7	0.4	11.8	0.7	0.4
propylmercaptan	1	9.3	2.8	20.6	0.0	0.0
butylmercaptan	1	28.9	0.0	618	0.0	0.0
dimethyldisulphide	1.76	672	4.8	6,501	4.3	1.6
dimethyltrisulphide	2.0	121	1.2	536	0.0	0.3
acetaldehyde	3	702	4.6	1,832	1.1	4.7
propenal	1	18.5	8.8	166	11.6	6.5
2-butenal	1	0.6	1.2	14,810	0.1	2.8
butanal	1	6.6	3.6	1,445	3.8	7.2
2-methylpropanal	0.54	40.2	30.8	231,058	67.3	115
2-methylpropenal	0.6	10.5	5.0	2,685	7.8	4.0
2-methylbutanal	0.3	13.6	68.3	742,995	168	401
3-methylbutanal	0.24	65.2	87.2	686,400	496	714
pentanal	0.5	352	8.6	21,835	7.3	50.4
hexanal	5.9	4.3	2.1	642	4.4	4.9
heptanal	0.7	9.9	4.1	1,574	12.4	20.1
acetic acid	9.0					
methanol	1000	0.3	0.2	43	0.3	0.4
ethanol	1750	8.1	3.5	119	0.3	0.2
i-propanol	500	1.6	0.5	45.0	0.0	0.1
propanol	600	0.8	0.4	12.9	0.0	0.0
t-butanol	1270	0.0	0.0	0.1	0.0	0.0
i-butanol	80	1.1	0.4	9.4	0.0	0.0
2-butanol	50	0.1	0.6	23.9	0.0	0.1
butanol	40	2.0	1.7	0.3	0.5	0.2
3-methylbutanol	80	0.0	0.1	11.4	0.0	0.1
acetone	420	3.7	0.4	101	0.8	0.4
2-butanone	9	4.7	1.6	551	1.4	1.0
3-buten-2-one	20	0.1	0.1	2.0	0.1	0.1
2,3-butanedione	20	1.3	0.6	62.6	0.9	0.6
methylisobutylketone	100	1.0	0.4	15.4	0.1	0.4
ethylacetate	710	0.1	0.0	1.0	0.0	0.0
benzene	6000	0.0	0.0	0.2	0.0	0.0
toluene	5000	0.0	0.0	0.4	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.8	0.0	0.0
chloroform	150	0.0	0.0	1.0	0.2	0.0
1,1,1-trichloroethane	150	0.0	0.0	0.3	0.0	0.0
trichloroethylene	150	0.0	0.0	1.6	0.0	0.0
tetrachloroethylene	150	0.0	0.0	0.1	0.0	0.0
methylcyclopentane	150	0.0	0.0	1.3	0.0	0.0
methylcyclohexane	150	0.0	0.0	0.1	0.0	0.0
cyclohexane	150	0.0	0.0	0.7	0.0	0.0
hexene	25	0.3	0.1	21.9	0.0	0.2
Sum Sulphurs	Sum Sulphurs	542,694	2,735	1,907,081	2,493	760
Sum Aldehydes	Sum Aldehydes	1,224	225	1,705,444	780	1,330
Sum others	Sum others	25	11	1,026	5	4
TOTAL ppb	**COU**	**543,943**	**2,971**	**3,613,551**	**3,277**	**2,094**
	OU	**602,000**	**15,600**	**275,000**	**1,190**	**3,560**
	ratio (OU/COU	1.1	5.3	0.1	0.4	1.7

Plant D	Threshold	BNR plant	Biofilter	Red Meat	Biofilter	Fish pile
nonpolar column	(ppb)		inlet	receival	outlet	
15-Nov-97						
component (ppb)		Chemical Odour Units				
hydrogen sulphide	0.25	399	271	997	6.7	247
carbonylsulphide	100	0.2	1.3	0.1	0.9	0.1
sulphurdioxide	9					
methylmercaptan	0.35	4,110	1,566	700	96.7	733
dimethylsulphide	0.97	31.8	6.6	7.5	0.0	27.5
carbondisulphide	20	0.8	1.0	0.5	0.3	0.3
ethylmercaptan	1					
i-propylmercaptan	1	0.3	0.0	0.0	0.0	0.0
propylmercaptan	1	0.2	0.0	0.0	0.0	0.0
dimethyldisulphide	1.76	22.9	4.2	1.9	0.3	3.8
dimethyltrisulphide	2.0	6.9	0.8	1.5	0.0	0.5
acetaldehyde	3	2.8	5.6	3.1	1.6	2.4
propenal	1	7.5	9.6	9.6	6.5	16.4
2-butenal	1	1.5	2.7	1.4	0.5	1.5
butanal	1	6.7	7.8	2.4	0.7	2.6
2-methylpropanal	0.54	25.1	526	10.8	3.2	35.5
2-methylpropenal	0.6	4.2	4.8	3.5	2.2	4.2
2-methylbutanal	0.3	30.5	986	8.4	3.4	33.3
3-methylbutanal	0.24	120	1,957	22.7	11.2	119
pentanal	0.5	11.1	52.1	3.5	2.5	17.2
hexanal	5.9	2.8	9.4	0.7	0.9	2.5
heptanal	0.7	15.6	33.7	3.6	4.9	10.4
methanol	1000	0.2	0.4	0.1	0.1	0.3
ethanol	1750	1.2	0.3	0.3	0.0	1.3
i-propanol	500	0.3	0.1	0.2	0.1	0.4
propanol	600	0.1	0.0	0.0	0.0	0.1
t-butanol	1270	0.0	0.0	0.0	0.0	0.0
i-butanol	80	1.1	0.0	0.0	0.0	0.0
2-butanol	50	0.3	0.0	0.1	0.0	0.3
butanol	40	0.3	0.1	0.1	0.0	0.3
3-methylbutanol	80	0.0	0.0	0.0	0.0	0.0
acetone	420	0.7	0.6	0.3	0.1	0.4
2-butanone	9	2.6	3.8	0.4	2.7	1.8
3-buten-2-one	20	0.0	0.2	0.1	0.0	0.8
2,3-butanedione	20	2.0	0.4	0.6	0.4	1.0
methylisobutylketone	100	1.4	0.1	0.1	0.0	0.2
ethylacetate	710	0.0	0.0	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.1
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0	0.4
chloroform	150	0.0	0.0	0.0	0.0	0.1
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0	0.0
trichloroethylene	150	0.0	0.0	0.0	0.0	0.0
tetrachloroethylene	150	0.0	0.2	0.0	0.0	0.0
methylcyclopentane	150	0.1	0.0	0.0	0.0	0.1
methylcyclohexane	150	0.0	0.0	0.0	0.0	0.0
cyclohexane	150	0.0	0.0	0.0	0.0	0.1
hexene	25	0.2	0.1	0.0	0.0	0.5
Sum Sulphurs	Sum Sulphurs	4,572	1,851	1,709	105	1,013
Sum Aldehydes	Sum Aldehydes	228	3,595	70	38	244
Sum others	Sum others	11	6	2	4	8
TOTAL ppb	**COU**	**4,810**	**5,452**	**1,782**	**146**	**1,266**
	OU	**3,360**	**7,150**	**5,650**	**930**	**5,070**
	ratio (OU/CO	0.70	1.31	3.17	6.35	4.01

Plant D	Threshold	Biofilter	Biofilter	BNR plant	Red Meat	Blood	Incinerator
nonpolar column	(ppb)	inlet	outlet		cooker	cooker	
23-Jan-98							
component (ppb)		Chemical Odour Units					
hydrogen sulphide	0.25	2,211	29.4	283	841	2,602	1,902,956
carbonylsulphide	100	0.4	0.4	0.1	0.3	0.3	57.2
sulphurdioxide	9						
methylmercaptan	0.35	9,827	1,982	161.7	2,515	14,580	612,060
dimethylsulphide	0.97	19.0	25.8	1.6	30.3	23.5	3,086
carbondisulphide	20	0.4	0.7	0.1	0.7	1.0	68.1
ethylmercaptan	1	10.1	30.2	1.4	35.8	4.6	1,264
i-propylmercaptan	1	0.2	0.4		3.0	0.4	165
propylmercaptan	1	1.5	1.3	0.1		0.2	172
dimethyldisulphide	1.76	80.0	38.2	2.6	12.3	57.8	1,768
dimethyltrisulphide	2.0	0.8	2.9				
acetaldehyde	3	14.8	3.2	1.9	36.4	37.1	2,146
propenal	1	24.3	10.3	7.5	27.5	20.0	1,192
2-butenal	1	2.2	1.2	0.6	1.2	1.2	13.4
butanal	1	39.8	0.7	1.3	5.3	5.6	510
2-methylpropanal	0.54	433	5.3	4.0	248	56.1	105,391
2-methylpropenal	0.6	8.0	2.3	3.4	6.4	6.5	315
2-methylbutanal	0.3	337	2.5	4.7	77.2	17.4	194,522
3-methylbutanal	0.24	1,643	9.5	10.7	564	148	383,969
pentanal	0.5						
hexanal	5.9	5.5	0.7	7.2	3.5	2.1	318
heptanal	0.7	34.4	6.5	20.5			
methanol	1000	0.6	0.2	0.4	0.3	0.3	11.3
ethanol	1750	4.6	0.5	0.3	1.0	6.6	12.9
i-propanol	500	0.4	0.0	0.1	0.2	0.4	3.5
propanol	600	0.5	0.0	0.1	0.1	0.6	4.1
t-butanol	1270	0.0	0.0	0.0	0.0	0.0	0.2
i-butanol	80	1.0	0.0	0.1	0.1	0.9	2.8
2-butanol	50	0.6	0.0	0.1	0.1	0.5	3.7
butanol	40	3.5	0.1	0.1	0.2	2.4	112
3-methylbutanol	80	0.2	0.0	0.0	0.1	0.1	1.5
acetone	420	0.9	0.1	0.2	0.7	0.5	73.1
2-butanone	9	15.2	0.3	0.4	1.1	1.1	194
3-buten-2-one	20	0.1	0.1	0.0	0.1	0.1	3.2
2,3-butanedione	20	1.6	0.5	0.3	1.6	1.2	32.8
methylisobutylketone	100	0.3	0.0	0.1	0.0	0.3	4.3
ethylacetate	710	0.2	0.0	0.0	0.0	0.2	0.5
benzene	6000	0.0	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.0	0.1
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0	0.0	1.0
chloroform	150	0.0	0.0	0.0	0.0	0.0	0.3
1,1,1-trichloroethane	150	0.0	0.0	0.0		0.0	0.7
trichloroethylene	150	0.0	0.0	0.0	0.0	0.0	0.8
tetrachloroethylene	150	0.0	0.1	0.0			0.0
methylcyclopentane	150	0.0	0.0	0.0		0.0	0.2
methylcyclohexane	150	0.0	0.0	0.0			0.1
cyclohexane	150		0.0			0.0	
hexene	25	0.3	0.2	0.1	0.4	0.4	10.0
Sum Sulphurs	Sum Sulphurs	12,150	2,112	450	3,439	17,270	2,521,595
Sum Aldehydes	Sum Aldehyd	2542	42	62	970	294	688377
Sum others	Sum others	30	2	2	6	16	473
TOTAL ppb	**COU**	**14,722**	**2,156**	**514**	**4,415**	**17,579**	**3,210,446**
	OU	**22,900**	**9,690**	**376**	**756**	**17,500**	**340,000**
	ratio (OU/C	1.6	4.5	0.7	0.2	1.0	0.1

Plant D	Threshold	Biofilter	Biofilter	BNR plant	Red Meat	Blood	Incinerator
polar column	(ppb)	inlet	outlet		cooker	cooker	
23-Jan-98							
component (ppb)		Chemical Odour Units					
hydrogen sulphide	0.25	276	32.7	22.1	1,603	17,384	130,517
carbonylsulphide	100	0.1	0.2	0.0	0.1	0.8	20.6
sulphurdioxide	9						
methylmercaptan	0.35	2,672	1,133	61.0	1,378	94,326	156,614
dimethylsulphide	0.97	2.1	14.6	0.9	11.2	11.8	935
carbondisulphide	20	0.0	0.2	0.1	0.1	1.2	23.4
dimethyldisulphide	1.76	7.9	2.9	0.7	0.7	124	1,082
dimethyltrisulphide	2.0	9.1	3.4	0.7	0.7	11.7	664
acetaldehyde	3	118	7.4	0.6	0.6	244	335
propenal	1						
propanal	1	49.5	4.1	6.2	4.9	726	4,846
butanal	1	9.6	0.5	1.3	3.3	12.0	225
2-methylpropanal	0.54	122	2.6	3.6	178	244	34,794
2-methylpropenal	0.6	5.0	2.1	1.8	2.4	13.9	83.2
2-methylbutanal	0.3	97.8	1.2	1.6	156	243	64,139
3-methylbutanal	0.24	305	2.3	2.7	463	728	144,980
pentanal	0.5	23.5	1.2	12.7	18.7	35.9	1,336
hexanal	5.9	0.8	0.1	2.0	0.6	2.8	38.1
heptanal	0.7	10.4	2.1	26.3	8.9	33.7	322
octanal	0.5	20.9	2.8	11.2	16.0	19.0	891
methanol	1000	1.1	0.1	0.2	0.2	0.5	2.6
ethanol	1750	1.5	0.2	0.2	0.5	43.2	8.1
i-propanol	500	0.2	0.0	0.0	0.2	1.9	4.0
propanol	600	0.3	0.0	0.0	0.1	4.2	2.5
acetone	420	0.2	0.0	0.1	0.2	1.0	8.3
2-butanone	9	0.8	0.1	0.3	0.7	6.1	53.9
benzene	6000	0.0	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.1	0.0	0.0	0.0	0.0	0.5
chloroform	150	0.0	0.0	0.0	0.0	0.0	0.2
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0	0.0	0.2
Sum Sulphurs	Sum Sulphurs	2,968	1,187	85	2,993	111,859	289,856
Sum Aldehydes	Sum Aldehyd	762	26.4	70.0	853	2,301	251,990
Sum others	Sum others	4.20	0.48	0.82	1.88	56.8	80.4
TOTAL ppb	**COU**	**3,734**	**1,213**	**156**	**3,848**	**114,217**	**541,927**
	OU	**22,900**	**9,690**	**376**	**756**	**17,500**	**340,000**
	ratio (OU/C	6.1	8.0	2.4	0.2	0.2	0.6

Plant E	Threshold	Drier	Non	Factory air	Drier	Raw
nonpolar column	(ppb)		condensables		Biofilter (out)	materials
17-Oct-97						
component		Chemical Odour Units				
hydrogen sulphide	0.25	101	117,401	466	202	117
carbonylsulphide	100	3.3	95.3	0.8	1.4	0.1
sulphurdioxide	9	0.2	1.5	0.1	0.1	0.0
methylmercaptan	0.35	295	44,068	1,449		257
dimethylsulphide	0.97	0.6	143	4.0	4.8	4.8
carbondisulphide	20	11.9	19.0	0.9	20.5	0.0
ethylmercaptan	1		831	2.0		
i-propylmercaptan	1		27.9			
propylmercaptan	1	1.3	9.8			0.1
dimethyldisulphide	1.76	0.7	44.0	1.5	0.5	0.5
dimethyltrisulphide	2.0					
acetaldehyde	3					
propenal	1	150	29.1	19.1	14.5	7.6
2-butenal	1	53.1	24.8	4.1	4.9	3.7
butanal	1	228	57.7	5.3	3.2	2.2
2-methylpropanal	0.54	392	3,185	461	21.1	8.4
2-methylpropenal	0.6	49.0	23.0	7.3	11.3	6.2
2-methylbutanal	0.3	277	10,451	963	15.7	3.5
3-methylbutanal	0.24	518	15,997	1,486	32.2	18.7
pentanal	0.5	1,809	1,256	169	547	16.0
hexanal	5.9	101	93.5	9.3	46.3	2.5
heptanal	0.7	559	415	31.3	107	14.4
methanol	1000	0.4	0.3	0.1	0.1	0.1
ethanol	1750	2.5	0.8	0.3	0.1	0.3
i-propanol	500	0.1	0.8	0.2	0.0	0.1
propanol	600	0.0	0.2	0.0	0.0	0.0
t-butanol	1270	0.0	0.0	0.0	0.0	0.0
i-butanol	80	0.2	0.5	0.1	0.0	0.0
2-butanol	50	0.1	1.6	0.1	0.0	0.0
butanol	40	1.6	1.8	0.2	0.4	0.0
3-methylbutanol	80	0.5	0.5	0.1	0.1	0.0
acetone	420	2.7	4.3	1.1	0.7	0.3
2-butanone	9	21.3	22.0	5.0	7.0	0.6
3-buten-2-one	20	6.5	0.9	0.3	0.1	0.5
2,3-butanedione	20	6.3	7.1	1.3	0.1	0.8
methylisobutylketone	100	0.5	2.6	0.2	0.1	0.1
ethylacetate	710	0.0	0.1	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.1	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.2	0.1	0.4	0.0	0.3
chloroform	150	0.1	0.3	0.0	0.0	0.1
1,1,1-trichloroethane	150	0.1	0.0	0.0	0.0	0.0
trichloroethylene	150	0.1	0.1	0.1	0.0	0.0
tetrachloroethylene	150	0.0	0.0	0.0	0.0	0.0
methylcyclopentane	150	0.0	0.1	0.2	0.2	0.0
methylcyclohexane	150	0.0	0.4	0.2	0.2	0.0
cyclohexane	150	0.1	0.3	0.2	0.3	0.0
hexene	25	35.2	0.3	0.3	47.9	0.4
heptene	25	32.5	1.6	0.6	56.0	0.2
octene	25	28.4	1.0	0.1	35.4	0.2
nonene	25	6.7	0.3	0.1	18.1	0.1
Sum Sulphurs	Sum Sulphurs	414	162,640	1,925	230	379
Sum Aldehydes	Sum Aldehydes	4,135	31,532	3,155	803	83
Sum others	Sum others	146	48	11	167	4
TOTAL (ppb)	**COU**	**4,695**	**194,220**	**5,091**	**1,200**	**467**
	OU/m^3	**37,000**	**220,000**	**21,600**	**19,100**	**2,050**
	ratio (OU/COU	7.9	1.1	4.2	15.9	4.4

Plant E	Threshold	Drier	Non	Factory air	Drier	Raw
polar column	(ppb)		condensables		Biofilter (out)	materials
17-Oct-97						
component (ppb)		Chemical Odour Units				
hydrogen sulphide	0.25	57.2	39,577	280		143
carbonylsulphide	100	1.8	14.8	0.4	0.4	0.0
sulphurdioxide	9				0.3	0.1
methylmercaptan	0.35	57.8	12,560	409	27.7	73.4
dimethylsulphide	0.97		126			0.5
carbondisulphide	20		0.0		3.1	
dimethyldisulphide	1.76	1.4	36.2	2.0	0.5	0.3
dimethyltrisulphide	2.0	1.1	36.8	3.1	0.3	0.2
acetaldehyde	3	9.2	9.6	2.3	2.0	1.2
propenal	1.0	5.1	12.0	2.9	0.9	0.0
propanal	1.0					
butanal	1.0	59.4	71.3	8.7	17.3	6.5
2-methylpropanal	0.54	274	1,307	253	9.7	3.9
2-methylpropenal	0.6	76.7	12.5	4.6	1.7	4.3
2-methylbutanal	0.3	241	1,840	421	37.3	4.3
3-methylbutanal	0.24	544	5,979	1,343	90.2	9.8
pentanal	0.5	562	193	30.4	92.5	15.7
hexanal	5.9	74.2	29.8	26.4	22.4	3.0
heptanal	0.7	473	151	43.6	14.1	20.9
octanal	0.5	70.7	70.5	15.7	71.3	32.4
methanol	1000	0.1	0.1	0.1	0.1	0.1
ethanol	1750	3.5	1.1	0.2	0.0	0.2
i-propanol	500	0.4	1.0	0.1	0.0	0.0
propanol	600	0.0	0.2	0.0	0.0	0.0
acetone	420	1.2	1.5	0.5	0.3	0.2
2-butanone	9	18.4	19.5	2.3	3.7	0.3
benzene	6000	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.3	0.0	0.1	0.7	0.1
chloroform	150	0.0	0.2	0.1	0.1	0.0
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0	0.0
Sum Sulphurs	Sum Sulphurs	119	52,352	695	32	218
Sum Aldehydes	Sum Aldehydes	2,388	9,677	2,152	359	102
Sum others	Sum others	24	24	4	5	1
TOTAL (ppb)	**COU**	**2,532**	**62,052**	**2,850**	**397**	**321**
	OU	**37,000**	**220,000**	**21,600**	**19,100**	**2,050**
	ratio (OU/COU)	14.6	3.5	7.6	48.2	6.4

Plant E	Threshold	Raw	Drier	Factory air	Drier	Non	Cookers
nonpolar column	(ppb)	materials			Biofilter (out)	condensables	insp. gantry
10-Nov-97							
component (ppb)		Chemical Odour Units					
hydrogen sulphide	0.25	869	480	232	39.5	459,581	1,317
carbonylsulphide	100	0.1	23.8	2.1	0.1	90.6	0.3
sulphurdioxide	9	0.0					
methylmercaptan	0.35	68.7	119	485	34.4	70,459	148
dimethylsulphide	0.97	0.9	166	8.8	1.6	179	0.4
carbondisulphide	20	0.7	25.3	1.0	2.6	21.3	0.4
ethylmercaptan	1			1.6		50.9	
i-propylmercaptan	1						
propylmercaptan	1						
dimethyldisulphide	1.76	0.8	15.3	2.6	0.1	31.8	0.2
dimethyltrisulphide	2.0						
acetaldehyde	3						
propenal	1	5.1		0.8	0.3	22.1	3.8
2-butenal	1	28.5	46.4	2.9	0.4	43.2	1.6
butanal	1	4.2	19.8	5.1		39.6	1.3
2-methylpropanal	0.54	6.1	142	139	4.3	4,316	23.9
2-methylpropenal	0.6	6.6	75.5	4.1	2.4	36.1	3.8
2-methylbutanal	0.3	18.4	117	369	8.8	14,145	66.1
3-methylbutanal	0.24	48.3	534	669	5.4	45,977	163
pentanal	0.5	49.0	215	226	46.6	701	60.6
hexanal	5.9	3.0	24.2	7.2	1.0	36.9	1.6
heptanal	0.7	22.6	169	15.3	5.7	176	9.6
methanol	1000	0.0	1.1	0.1	0.0	0.6	0.1
ethanol	1750	0.1	0.4	0.8	0.0	2.2	0.1
i-propanol	500	0.0	0.6	0.0	0.0	0.4	0.0
propanol	600	0.0	0.1	0.0	0.0	0.2	0.0
t-butanol	1270	0.0	0.8	0.0	0.0	0.0	0.0
i-butanol	80	0.0	1.1	0.0	0.0	0.0	0.0
2-butanol	50	0.0	0.9	0.1	0.0	0.2	0.0
butanol	40	0.1	1.7	2.2	0.6	0.3	0.1
3-methylbutanol	80	0.0	1.0	0.1	0.0	0.3	0.0
acetone	420	0.3	5.1	0.7	0.2	2.5	0.3
2-butanone	9	0.7	32.1	3.2	0.0	9.5	0.5
3-buten-2-one	20	0.3	5.2	0.2	0.3	0.7	0.2
2,3-butanedione	20	0.3	3.4	0.6	0.2	7.4	0.3
methylisobutylketone	100	0.1	1.9	0.1	0.1	0.5	0.1
ethylacetate	710	0.0	0.1	0.0	0.0	0.0	0.0
benzene	6000	0.0	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.1	0.3	0.1	0.4	0.4	0.0
chloroform	150	0.0	0.3	0.0	0.0	0.1	0.0
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.1	0.1	0.0
trichloroethylene	150	0.0	0.3	0.0	0.0	0.8	0.0
tetrachloroethylene	150	0.0	0.4	0.0	0.0	0.0	0.0
methylcyclopentane	150	0.0	0.1	0.0	0.0	0.0	0.0
methylcyclohexane	150	0.0	0.3	0.0	0.1	0.0	0.0
cyclohexane	150	0.0	0.0	0.1	0.1	0.0	0.0
hexene	25	0.1	0.1	0.4	0.9	0.0	0.2
heptene	25	0.1	0.1	0.3	0.8	0.0	0.2
octene	25	0.1	0.1	0.3	0.7	0.0	0.2
nonene	25	0.1	0.1	0.2	0.6	0.0	0.1
Sum Sulphurs	Sum Sulphurs	940	830	733	78	530,414	1,466
Sum Aldehydes	Sum Aldehydes	192	1,344	1,440	75	65,494	335
Sum others	Sum others	3	57	10	5	27	3
TOTAL ppb	**COU**	**1,134**	**2,231**	**2,182**	**159**	**595,935**	**1,804**
	OU	**756**	**30,900**	**10,600**	**508**	**8,700,000**	**10,700**
	ratio (OU/CO	0.7	13.8	4.9	3.2	14.6	5.9

Plant E	Threshold	**Raw**	**Drier**	**Factory air**	**Drier**	**Non**	**Cookers**
polar column	(ppb)	**materials**			**Biofilter (out)**	**condensables**	**insp. gantry**
10-Nov-97							
component (ppb)		**Chemical Odour Units**					
hydrogen sulphide	0.25	401	575	306	47.9	142,459	1,048
carbonylsulphide	100	0.0	1.5	1.2	0.1	44.6	0.3
sulphurdioxide	9						
methylmercaptan	0.35	62.4	265	142	7.5	29,138	123
dimethylsulphide	0.97	0.0	3.5	1.8	1.1	63.6	0.0
carbondisulphide	20	0.0	0.1	0.0	0.0	6.7	0.0
dimethyldisulphide	1.76	0.4	0.9	1.4	0.1	15.3	0.8
dimethyltrisulphide	2.0	0.9	0.9	2.7	0.1	55.8	4.3
acetaldehyde	3	2.0	42.1	7.0	8.8	135	1.6
propenal	1	2.6	5.2	7.4	3.5	33.0	12.0
propanal	1						
butanal	1	0.5	1.5	4.6	0.5	23.2	3.5
2-methylpropanal	0.54	3.1	3.1	89.8	2.1	3,221	30.9
2-methylpropenal	0.6	1.7	1.8	2.1	1.1	16.3	3.5
2-methylbutanal	0.3	4.4	2.4	84.4	0.8	6,327	112
3-methylbutanal	0.24	10.9	12.2	233	8.3	23,768	155
pentanal	0.5	3.4	3.4	19.1	3.1	101	7.3
hexanal	5.9	1.3	1.0	3.1	1.0	37.4	2.4
heptanal	0.7	10.0	7.4	15.7	5.2	220	15.5
octanal	0.5	22.1	18.3	31.6	8.3	468	49.8
methanol	1000	0.0	0.0	0.1	0.0	0.3	0.1
ethanol	1750	0.1	2.0	0.5	0.0	1.2	0.1
i-propanol	500	0.0	0.1	0.0	0.0	0.2	0.0
propanol	600	0.0	0.0	0.0	0.0	0.3	0.0
acetone	420	0.1	1.0	0.3	0.1	0.8	0.1
2-butanone	9	0.2	1.0	1.9	0.1	4.8	0.5
benzene	6000	0.0	0.0	0.0	0.0	0.0	0.0
toluene	5000	0.0	0.0	0.0	0.0	0.0	0.0
ethylbenzene	10000	0.0	0.0	0.0	0.0	0.0	0.0
m,p-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
o-xylene	10000	0.0	0.0	0.0	0.0	0.0	0.0
dichloromethane	150	0.0	0.0	0.0	0.0	0.0	0.0
chloroform	150	0.0	0.0	0.0	0.0	0.0	0.0
1,1,1-trichloroethane	150	0.0	0.0	0.0	0.0	0.0	0.0
Sum Sulphurs	Sum Sulphurs	465	847	456	57	171,784	1,176
Sum Aldehydes	Sum Aldehydes	62	98	498	43	34,349	394
Sum others	Sum others	0	4	3	0	8	1
TOTAL ppb	**COU**	**527**	**949**	**956**	**100**	**206,141**	**1,570**
	OU	**756**	**30,900**	**10,600**	**508**	**8,700,000**	**10,700**
	ratio (OU/COU	1.4	32.6	11.1	5.1	42.2	6.8

Figure 5. Chemical Odour Distribution for Plant A, 18 Dec 1997

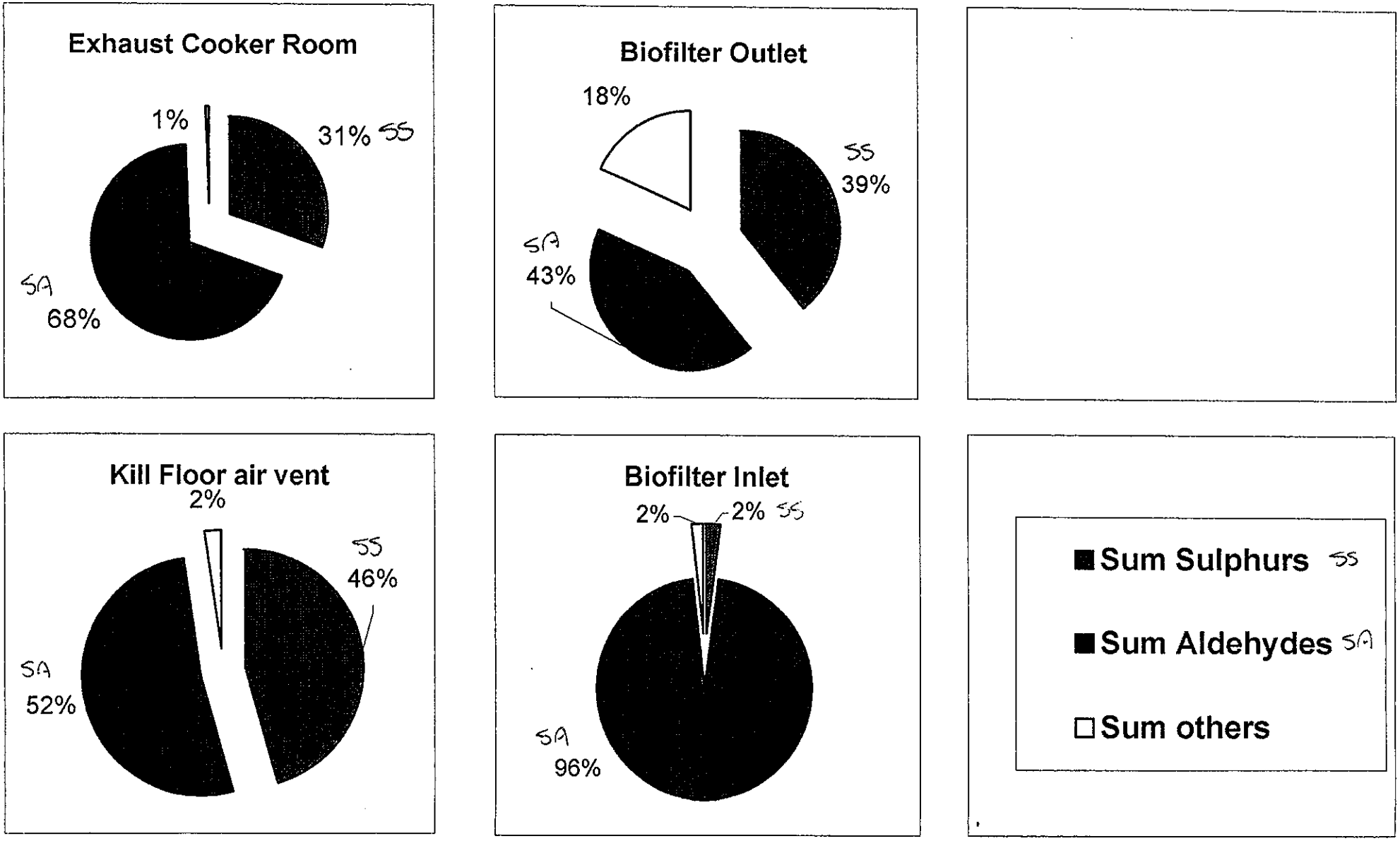


Figure 6. Chemical Odour Distribution for Plant B, 19 Nov 1997

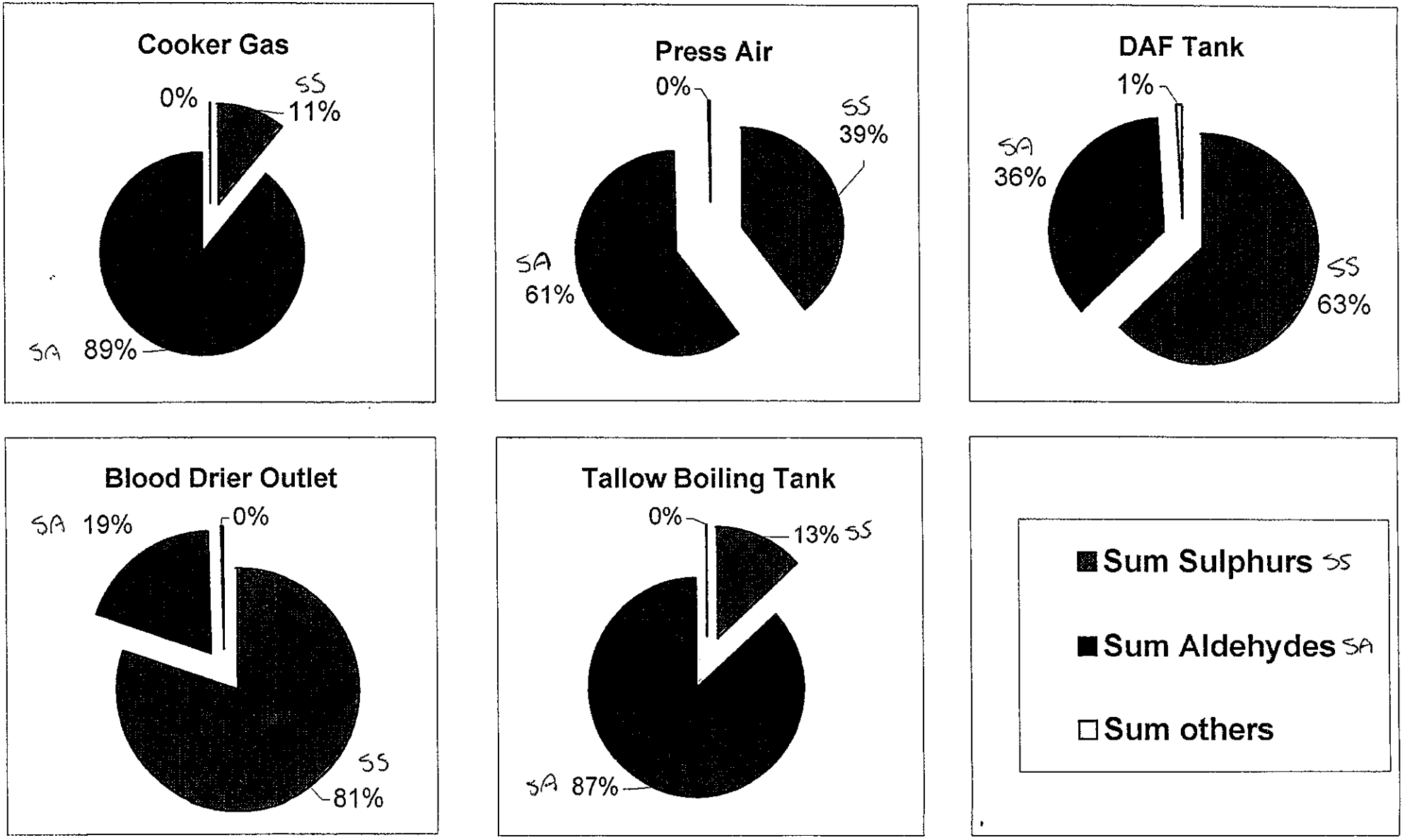
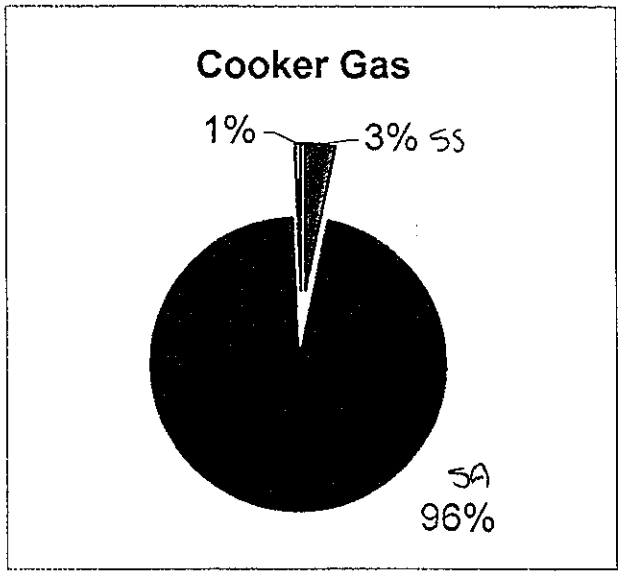
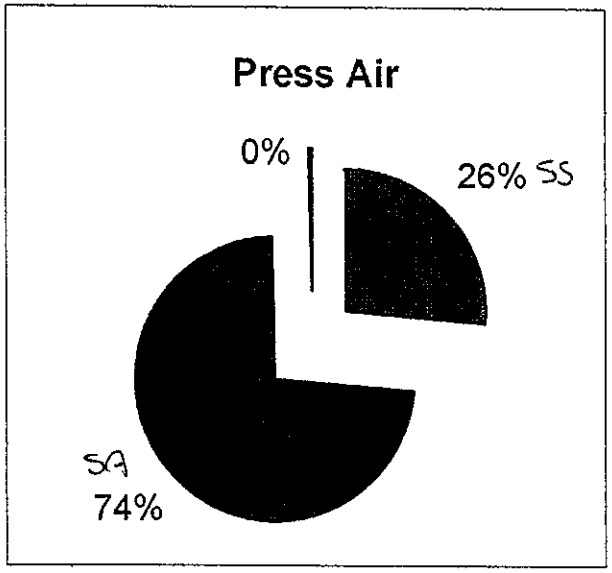
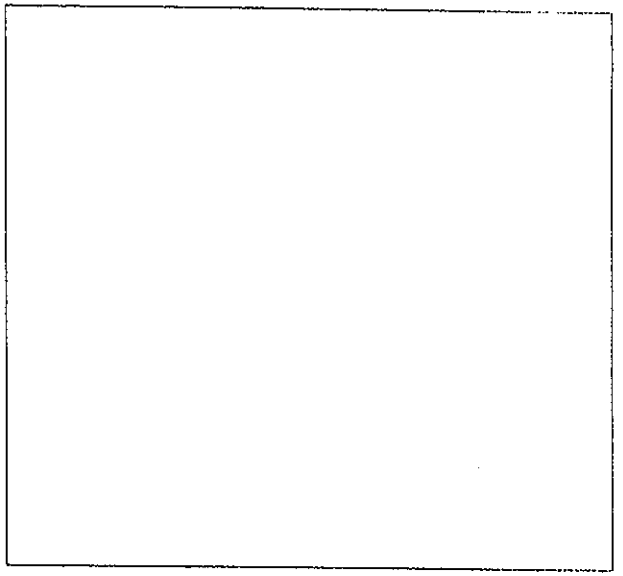
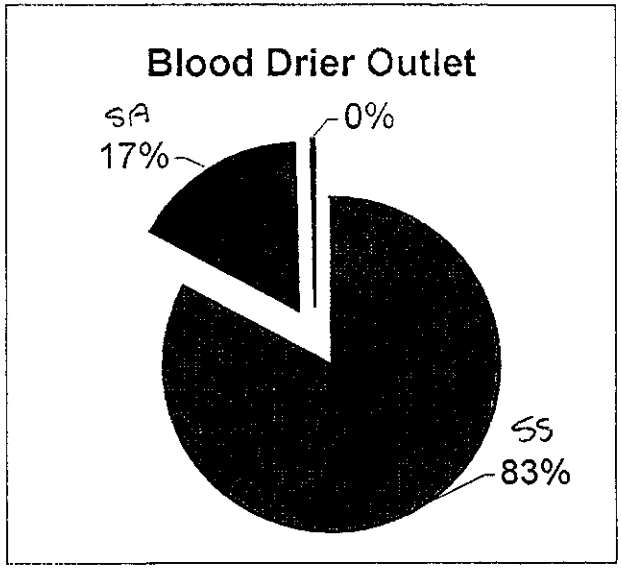


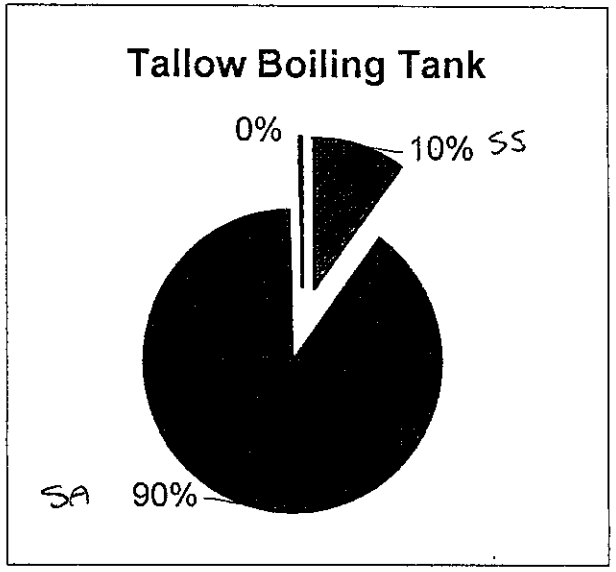
Figure 7: Chemical Odour Distribution for Plant B, 19 Dec 1997











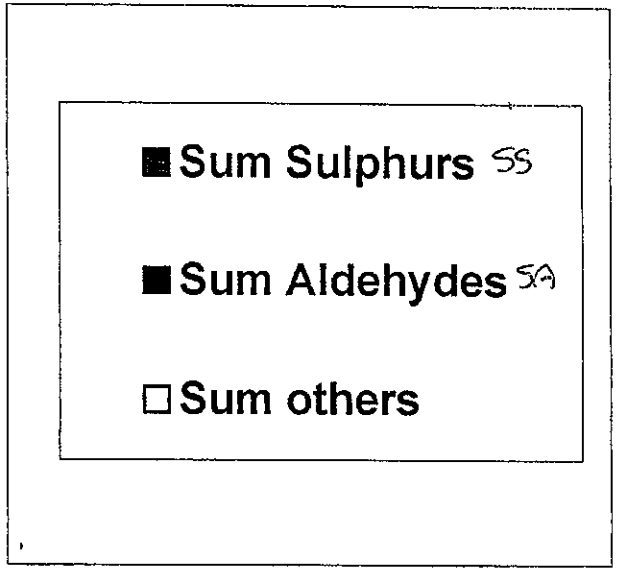


Figure 8. Chemical Odour Distribution for Plant C, 26 Nov 1997

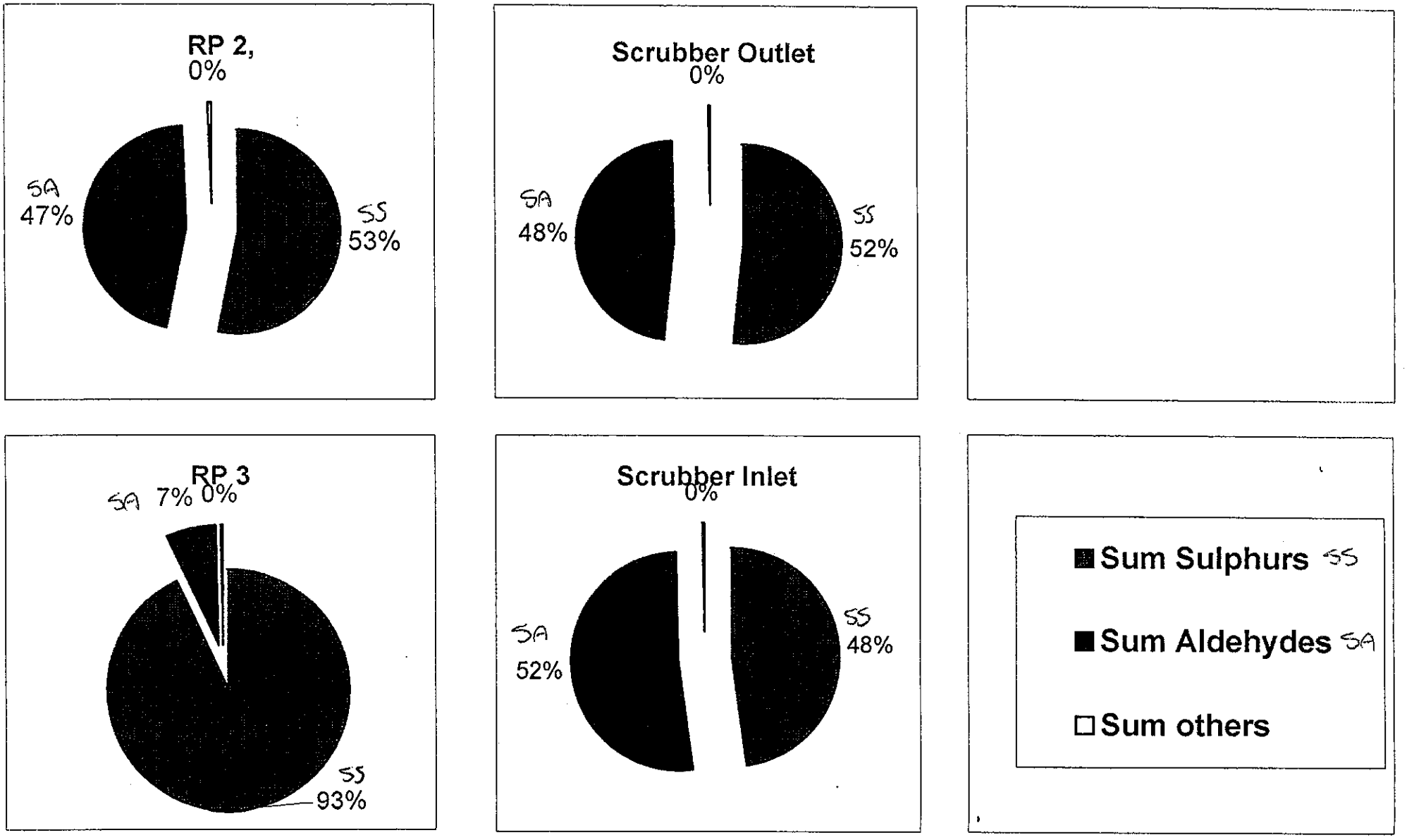


Figure 9. Chemical Odour Distribution for Plant C, 4 Mar 1998

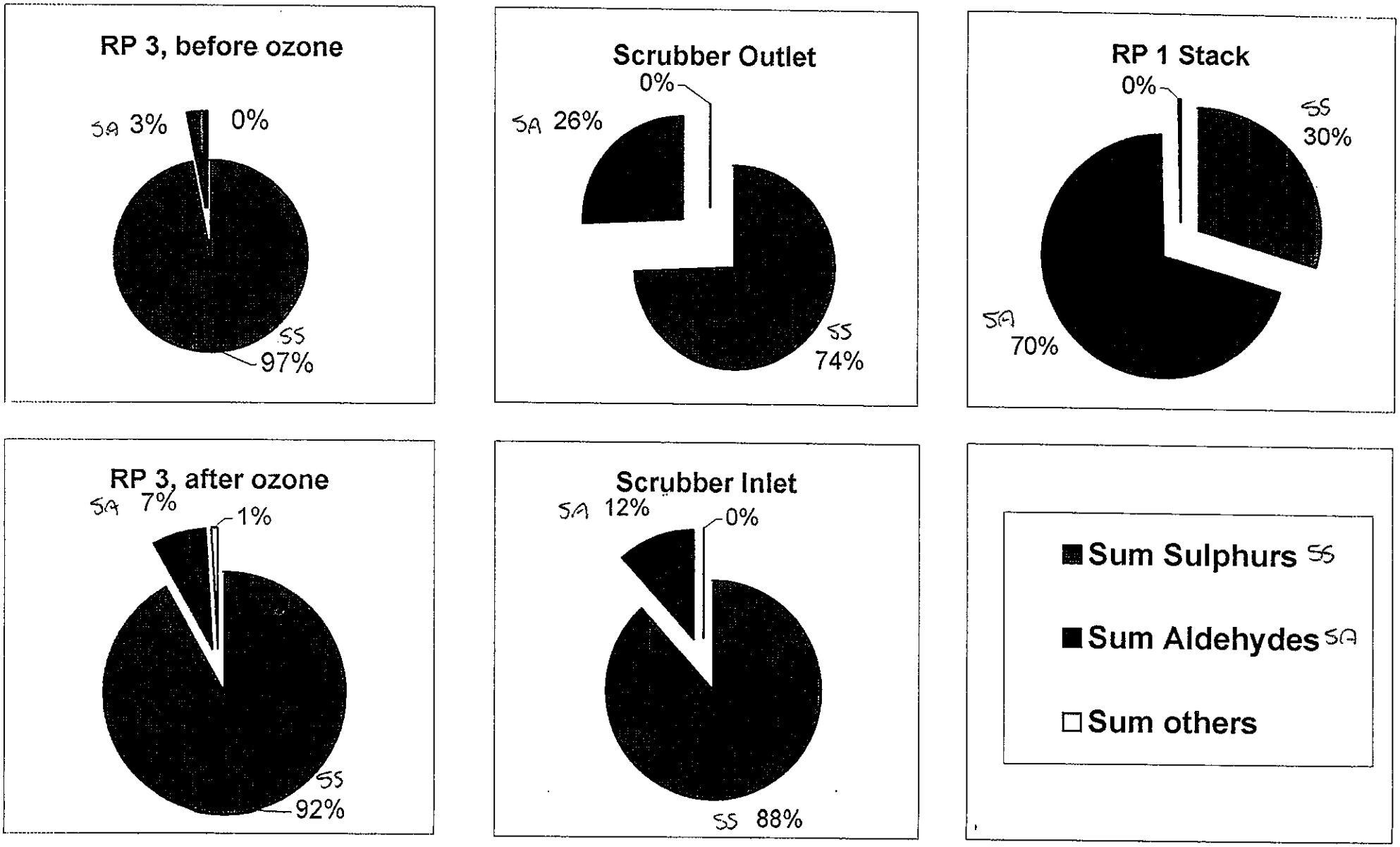


Figure 10. Chemical Odour Distribution for Plant D, 15 Nov 1997 (1)

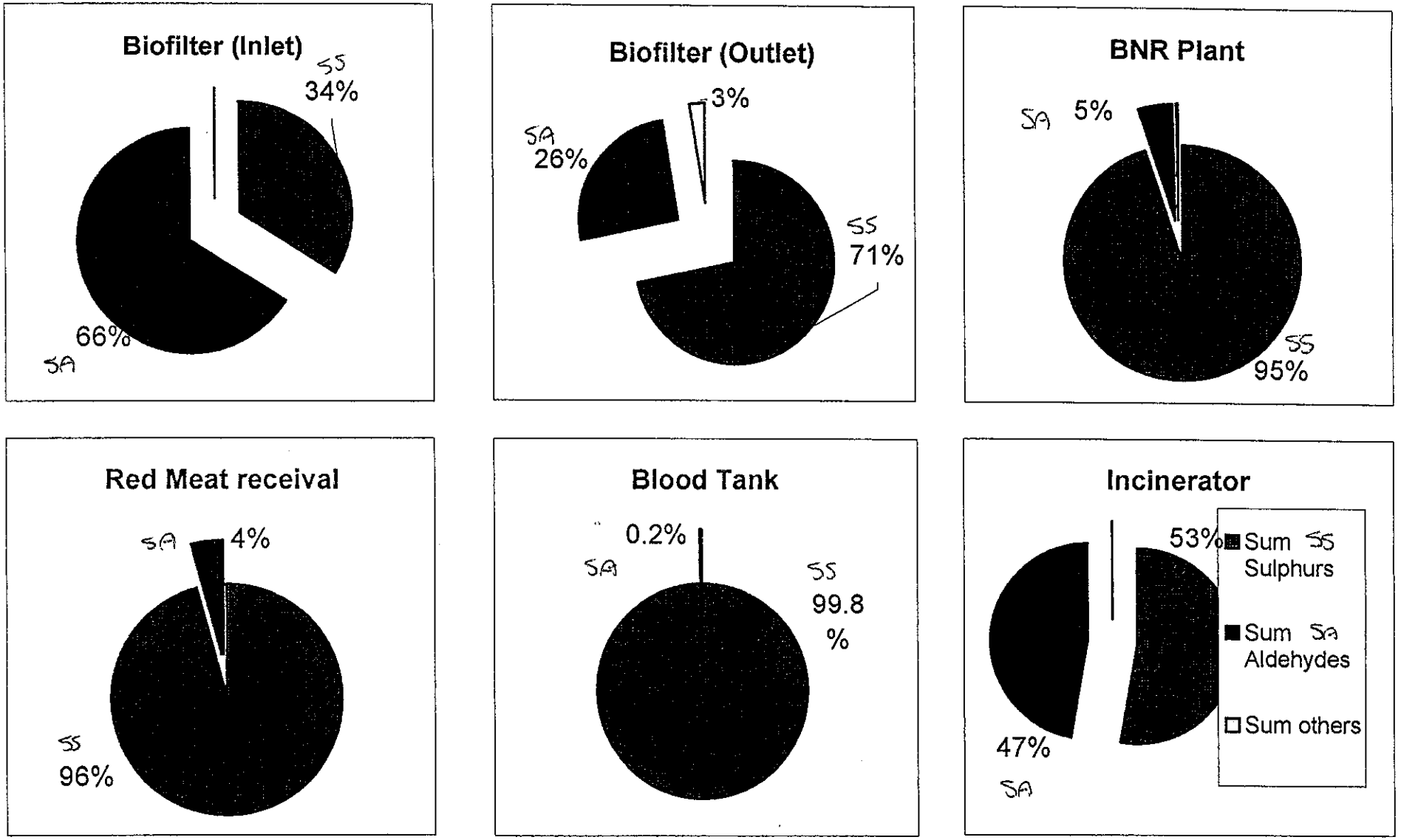


Figure 11. Chemical Odour Distribution for Plant D, 15 Nov 1997 (2)

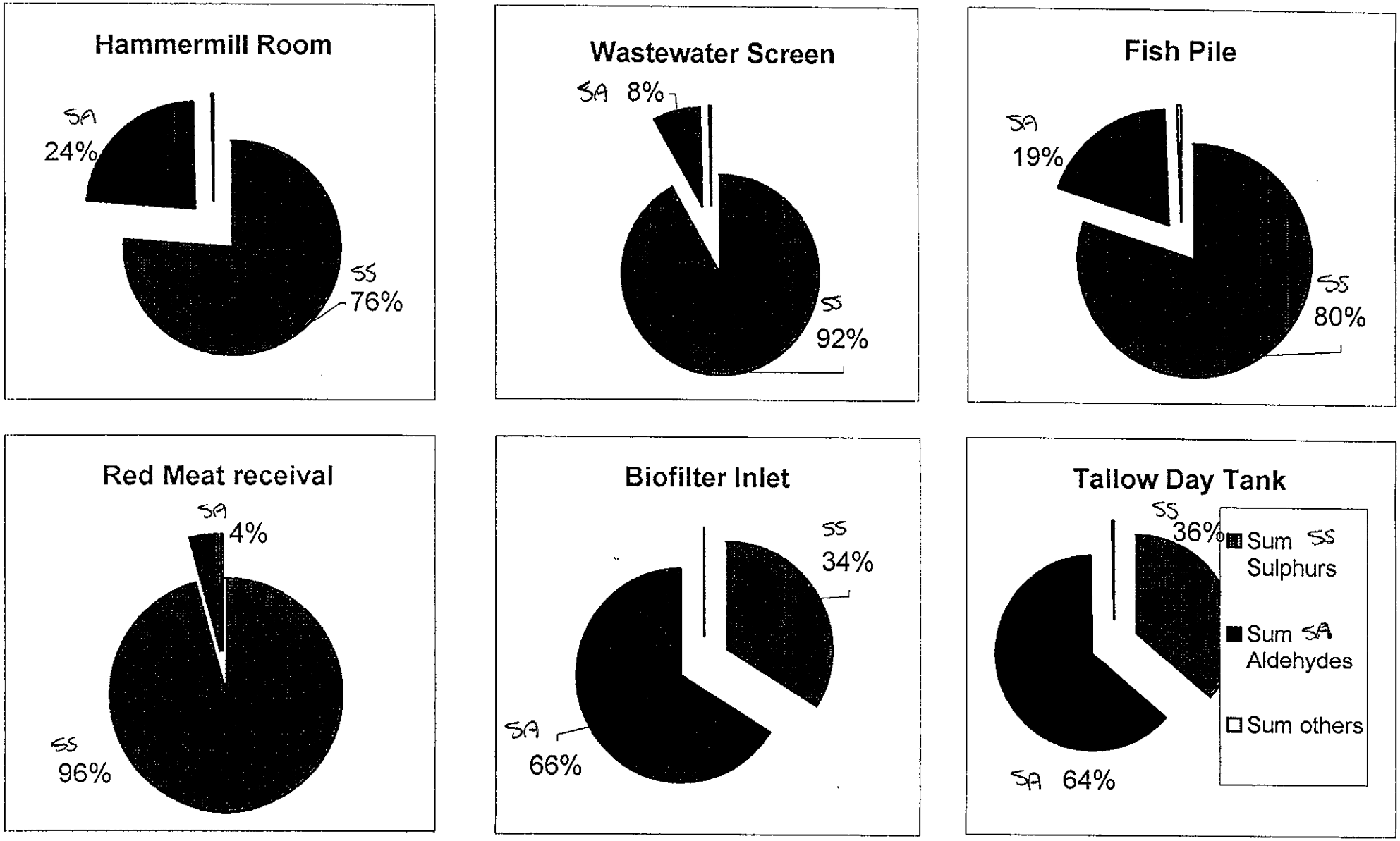


Figure 12. Chemical Odour Distribution for Plant D, 23 Jan 1998

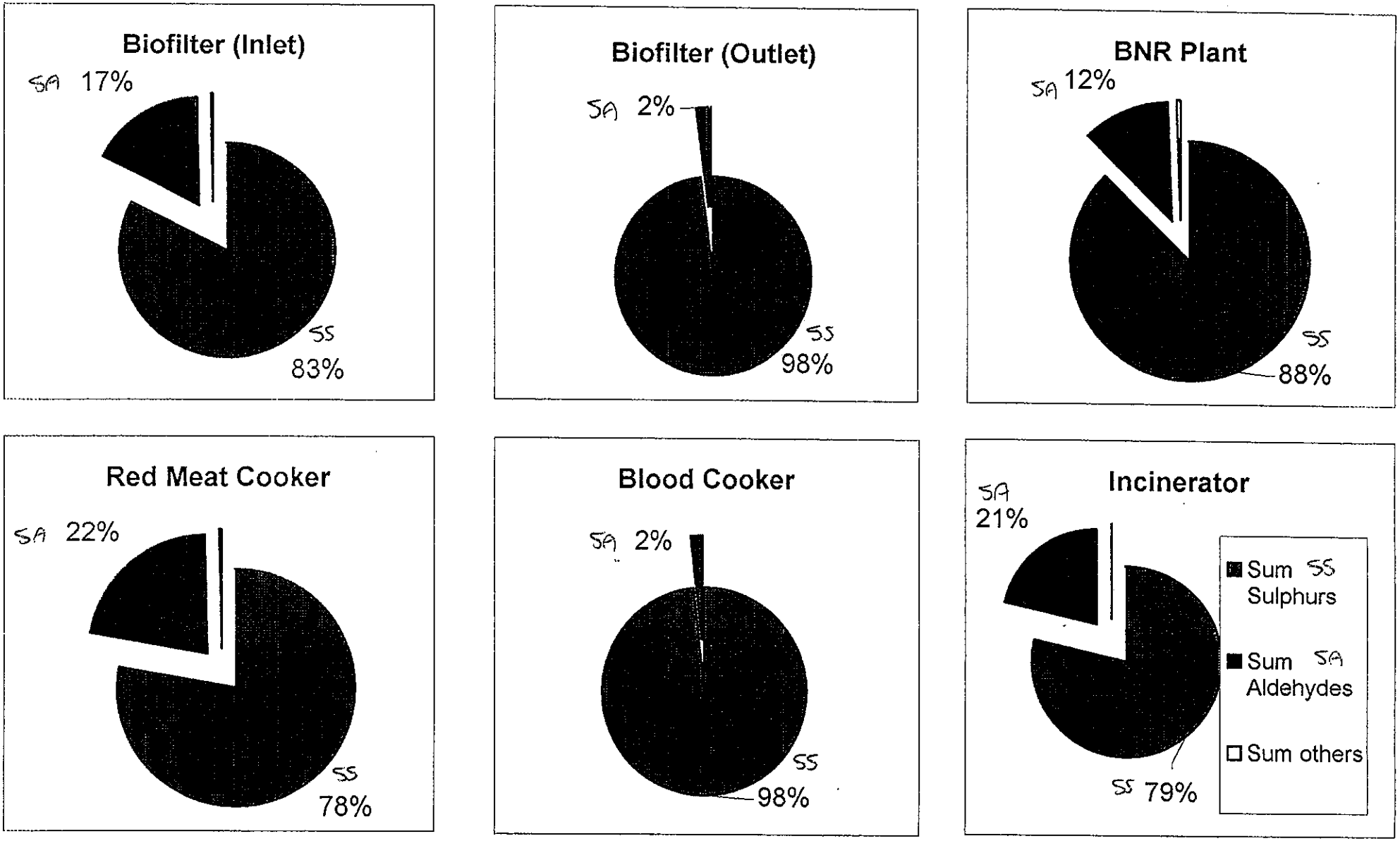


Figure 13. Chemical Odour Distribution for Plant E, 17 Oct 1997

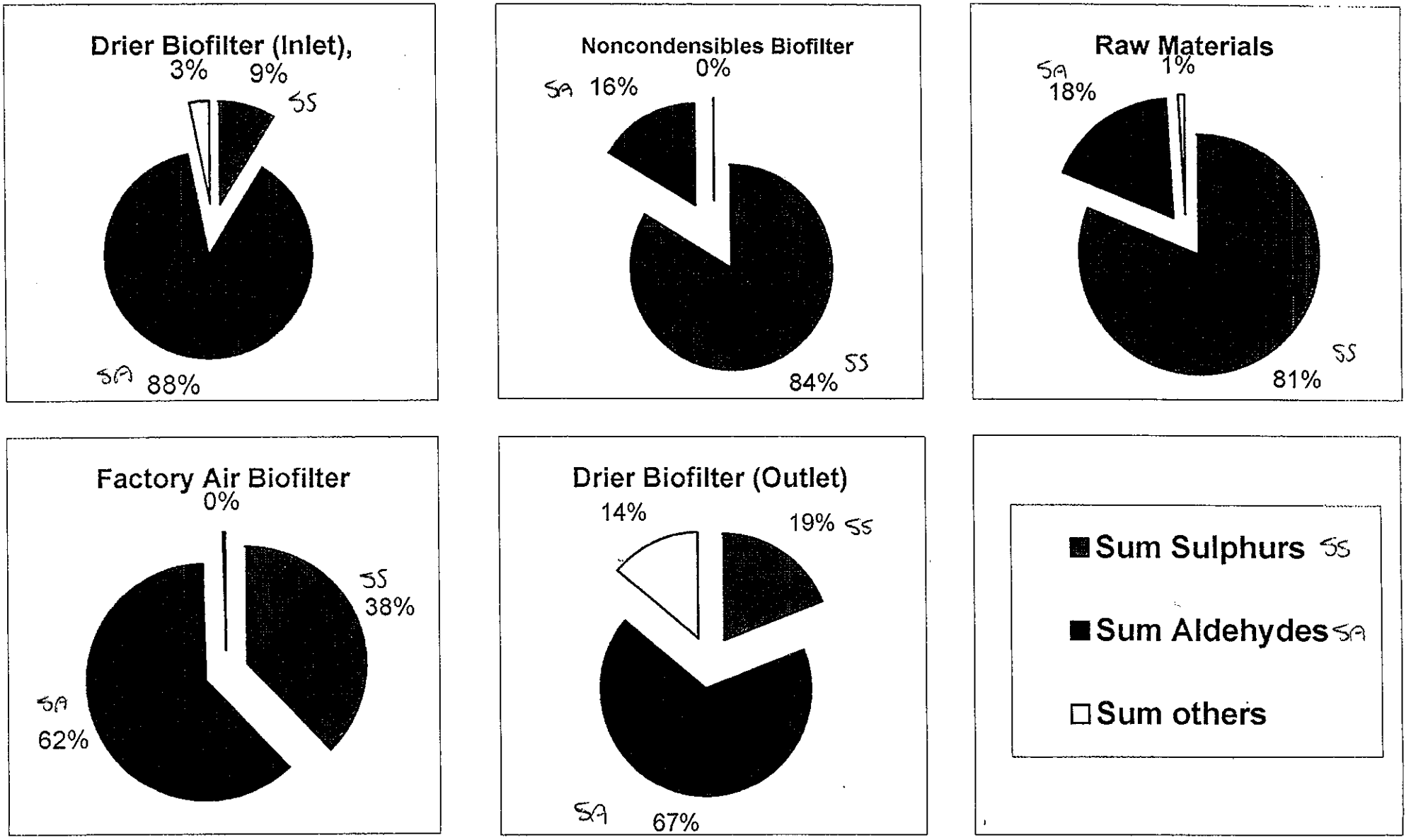
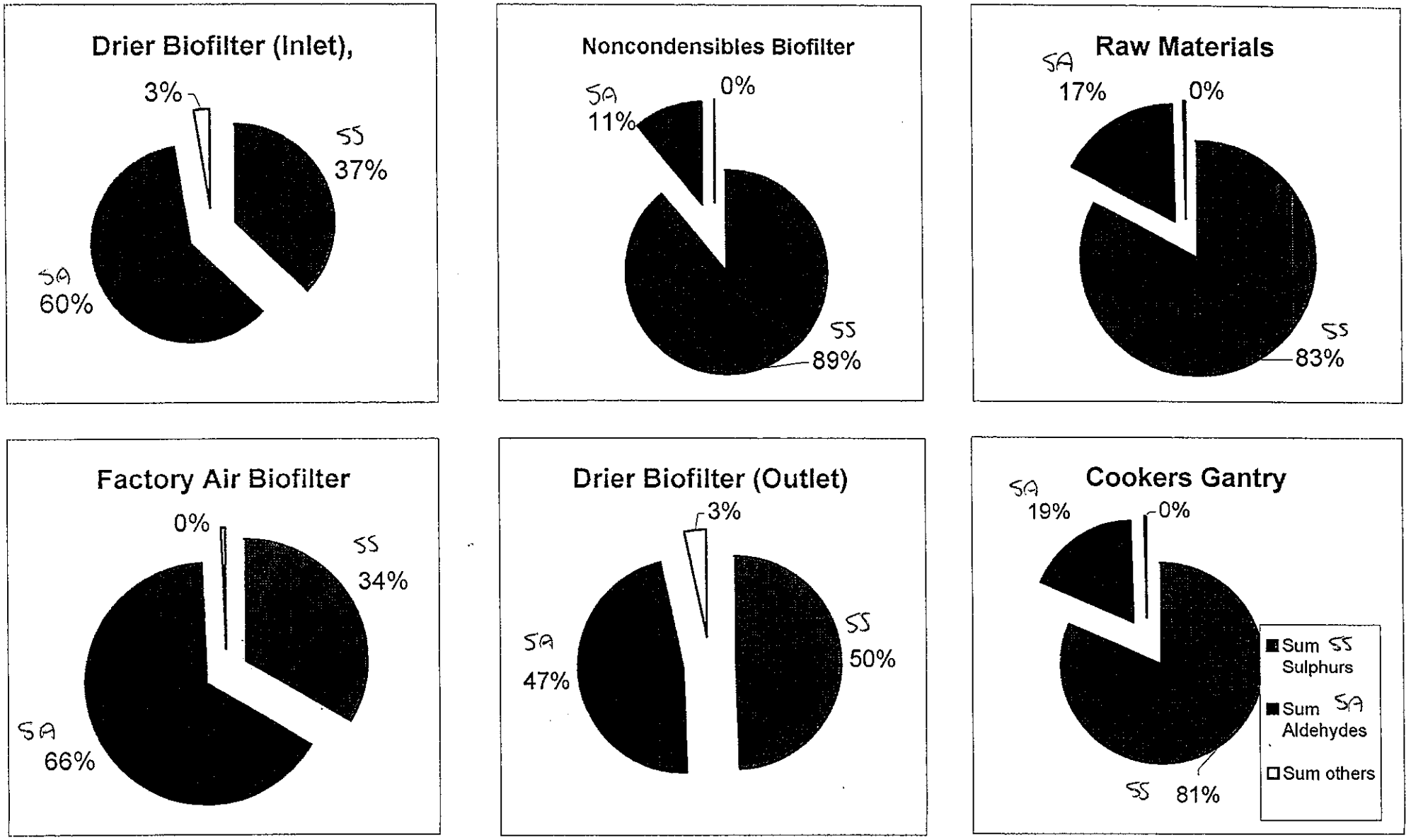


Figure 14. Chemical Odour Distribution for Plant E, 10 Nov 1997



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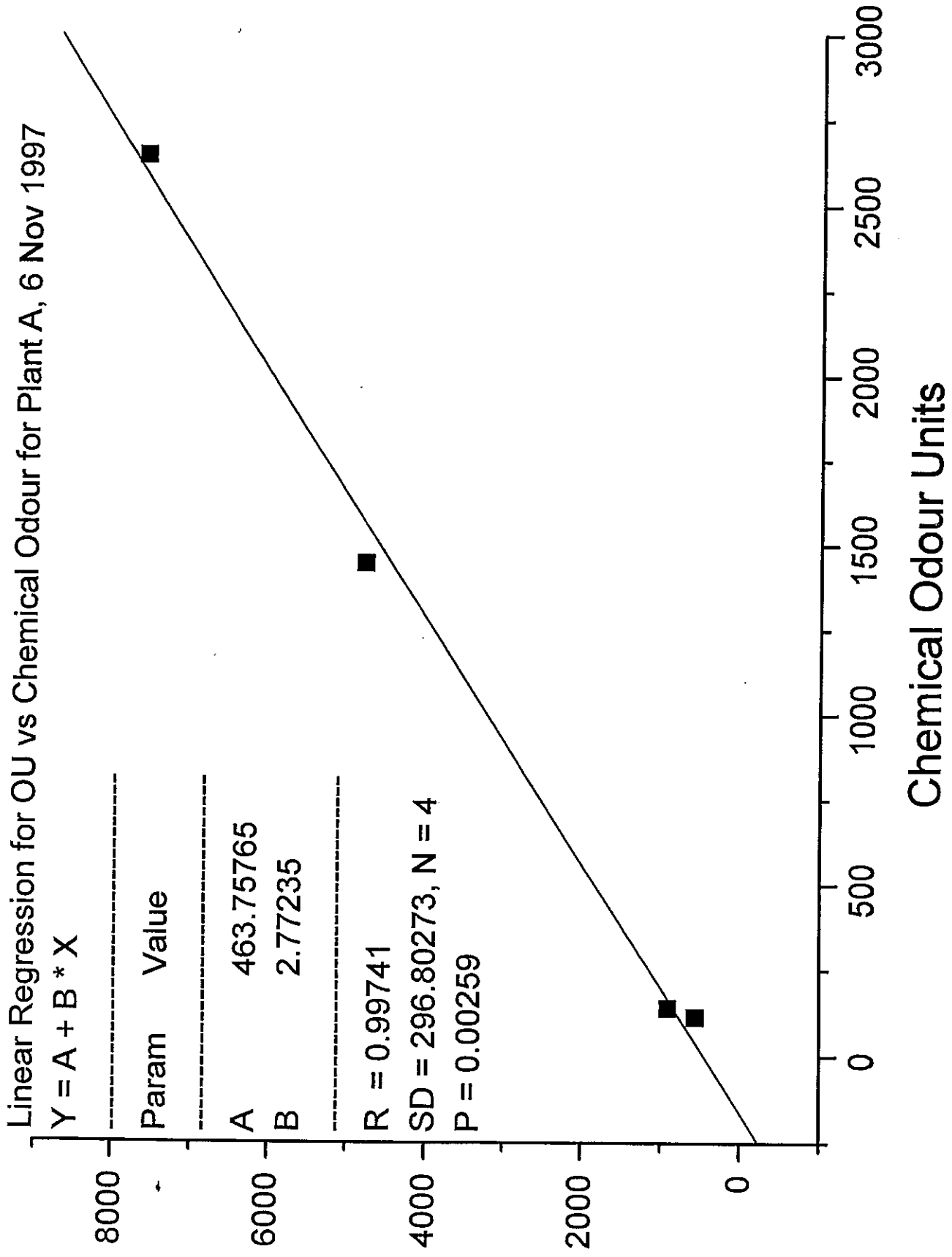
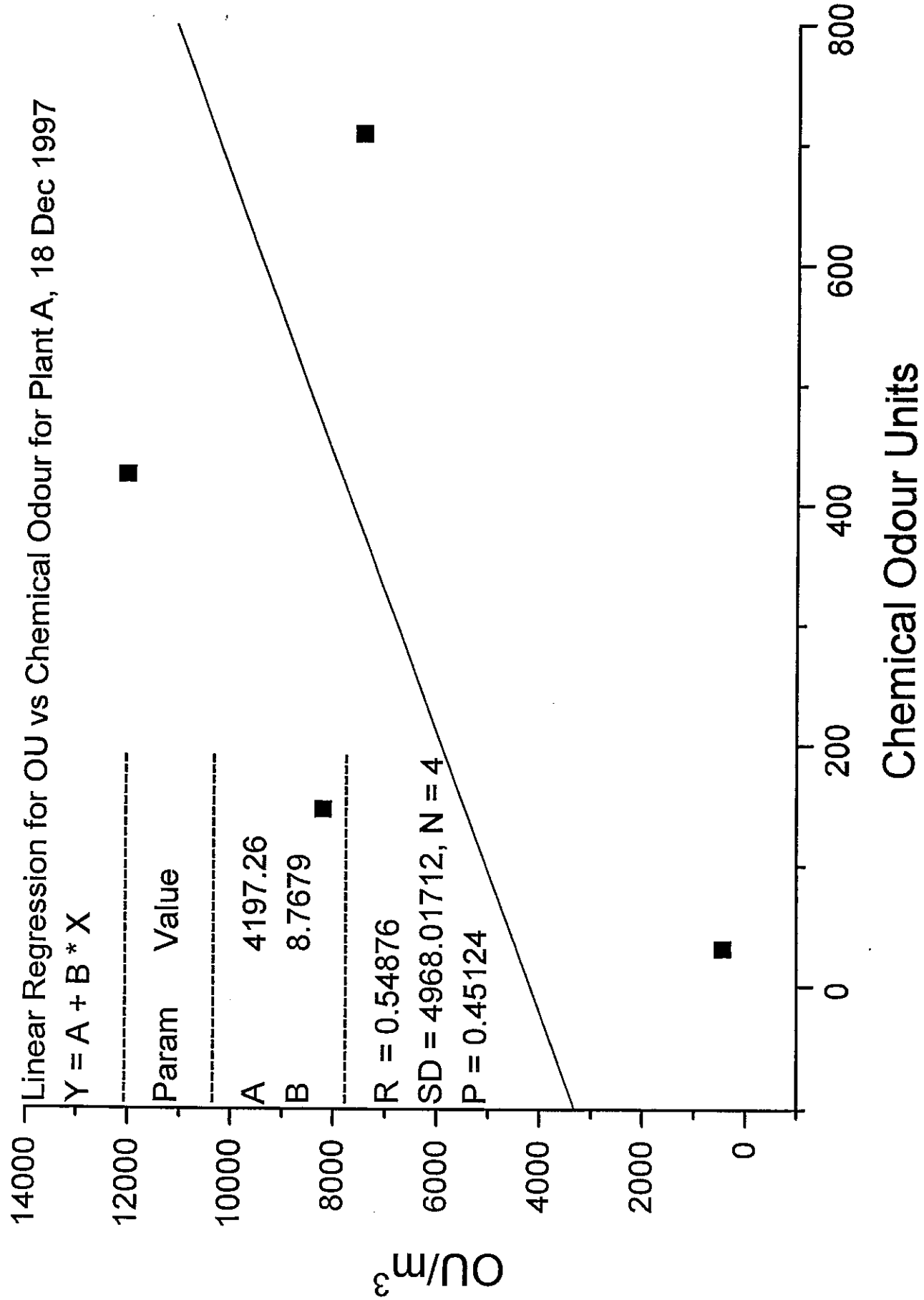
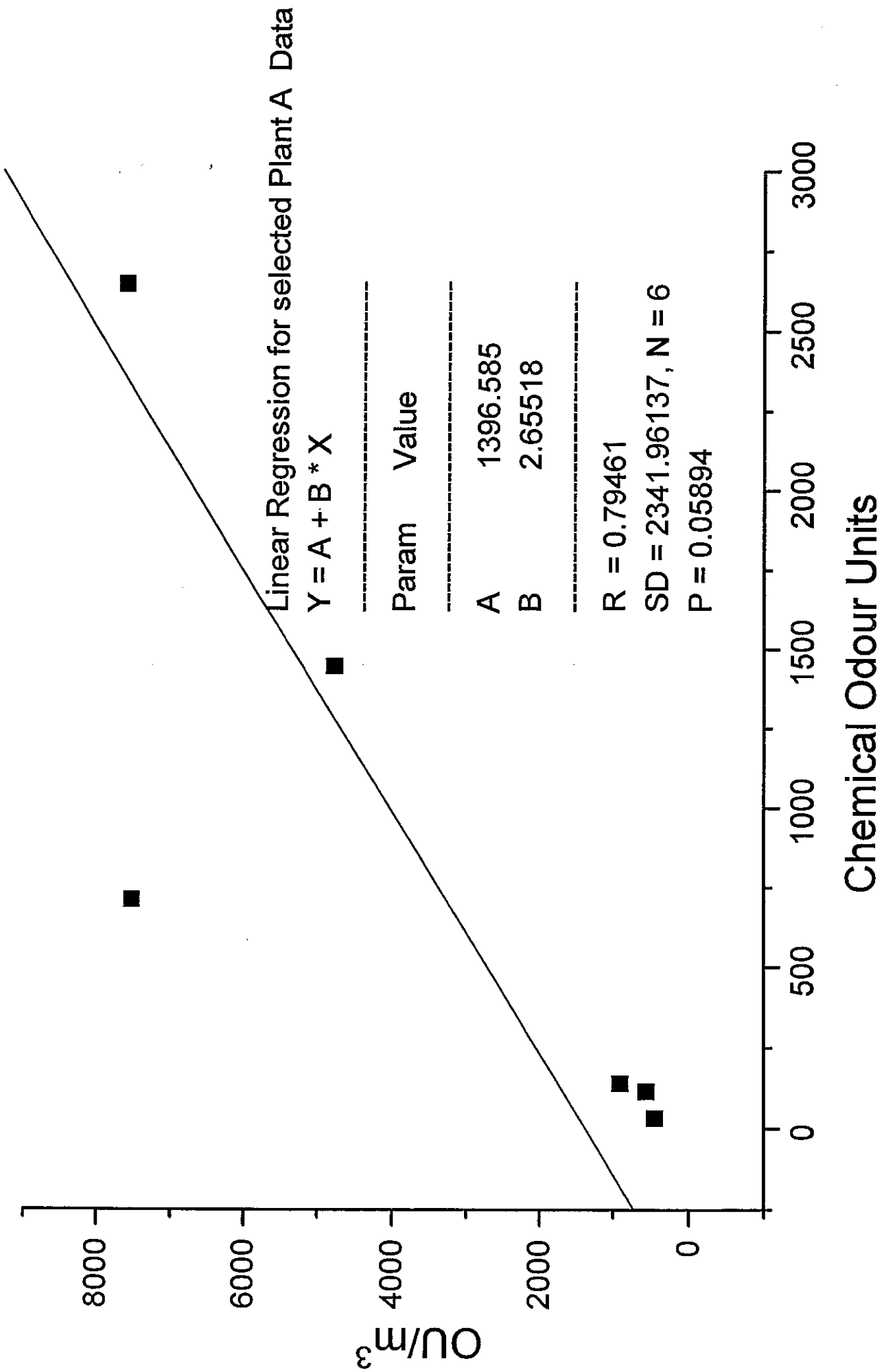
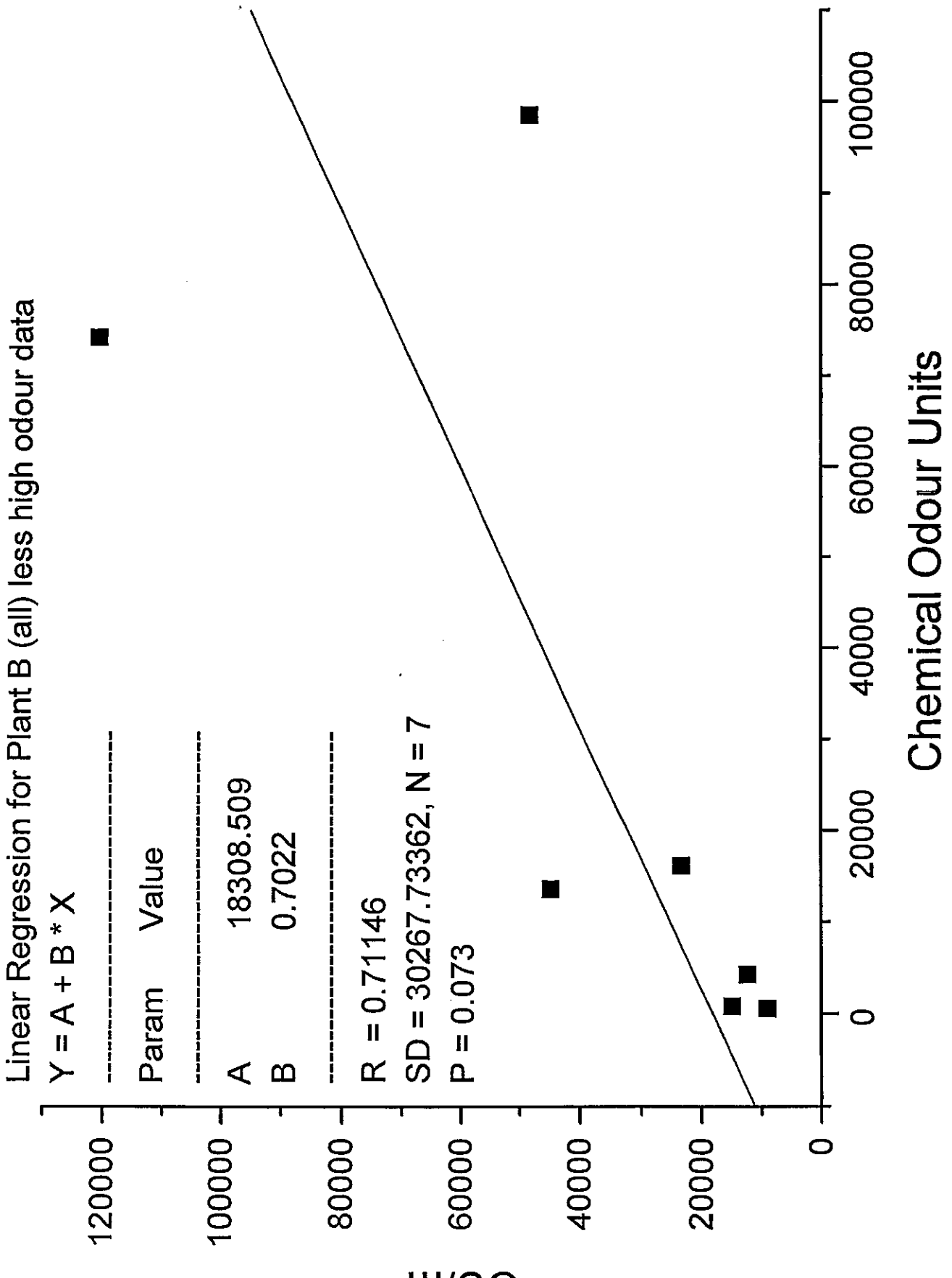
APPENDIX 4

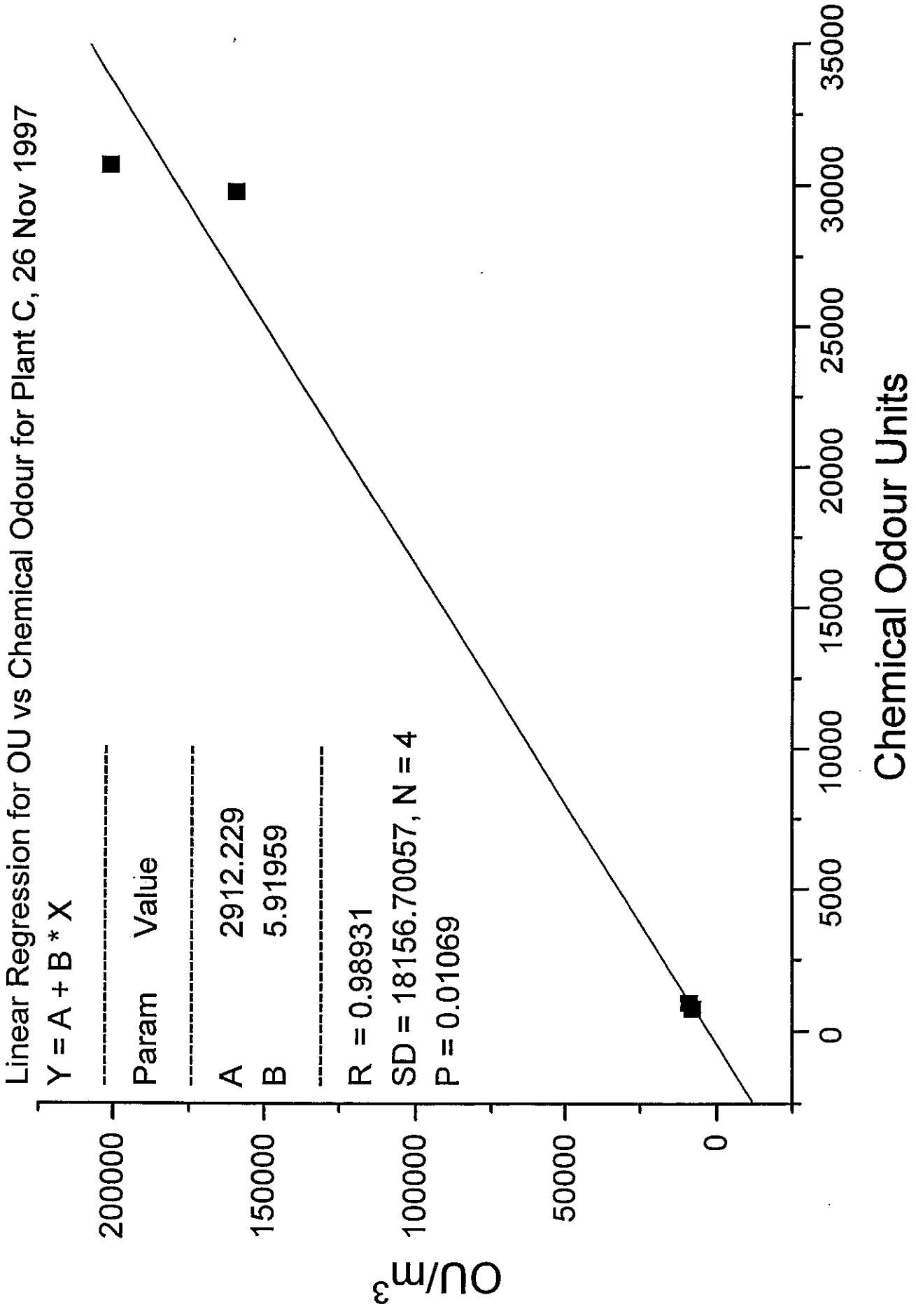
LINEAR REGRESSION ANALYSIS (CHEMICAL ODOUR/ODOUR UNITS)

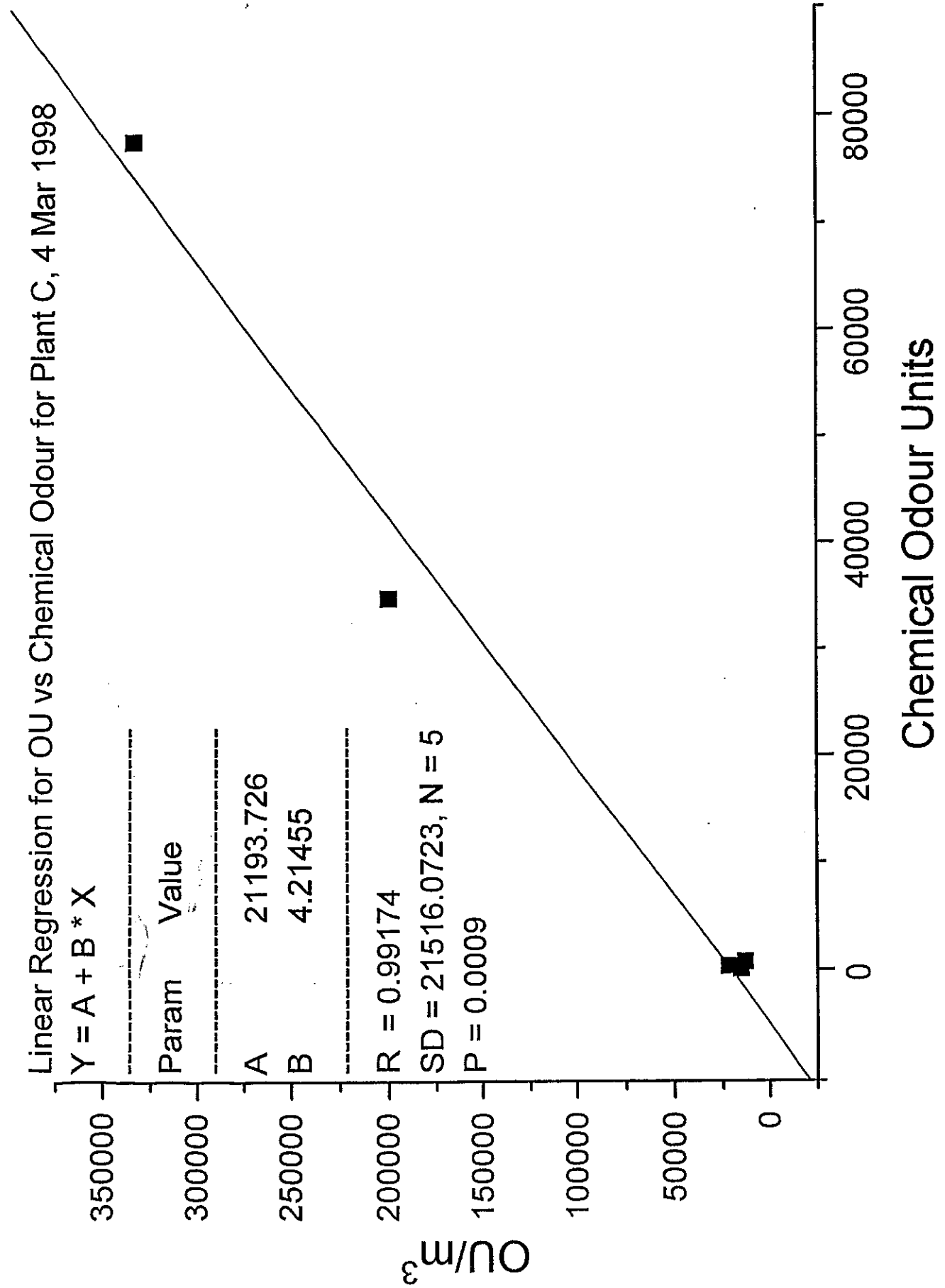

Linear Regression for OU vs Chemical Odour for Plant A, 6 Nov 1997
Y = A + B * X
Param Value
A 463.75765
B 2.77235
R = 0.99741
SD = 296.80273, N = 4
P = 0.00259
OU/m³
8000
6000
4000
2000
0
0
500
1000
1500
2000
2500
3000
Chemical Odour Units

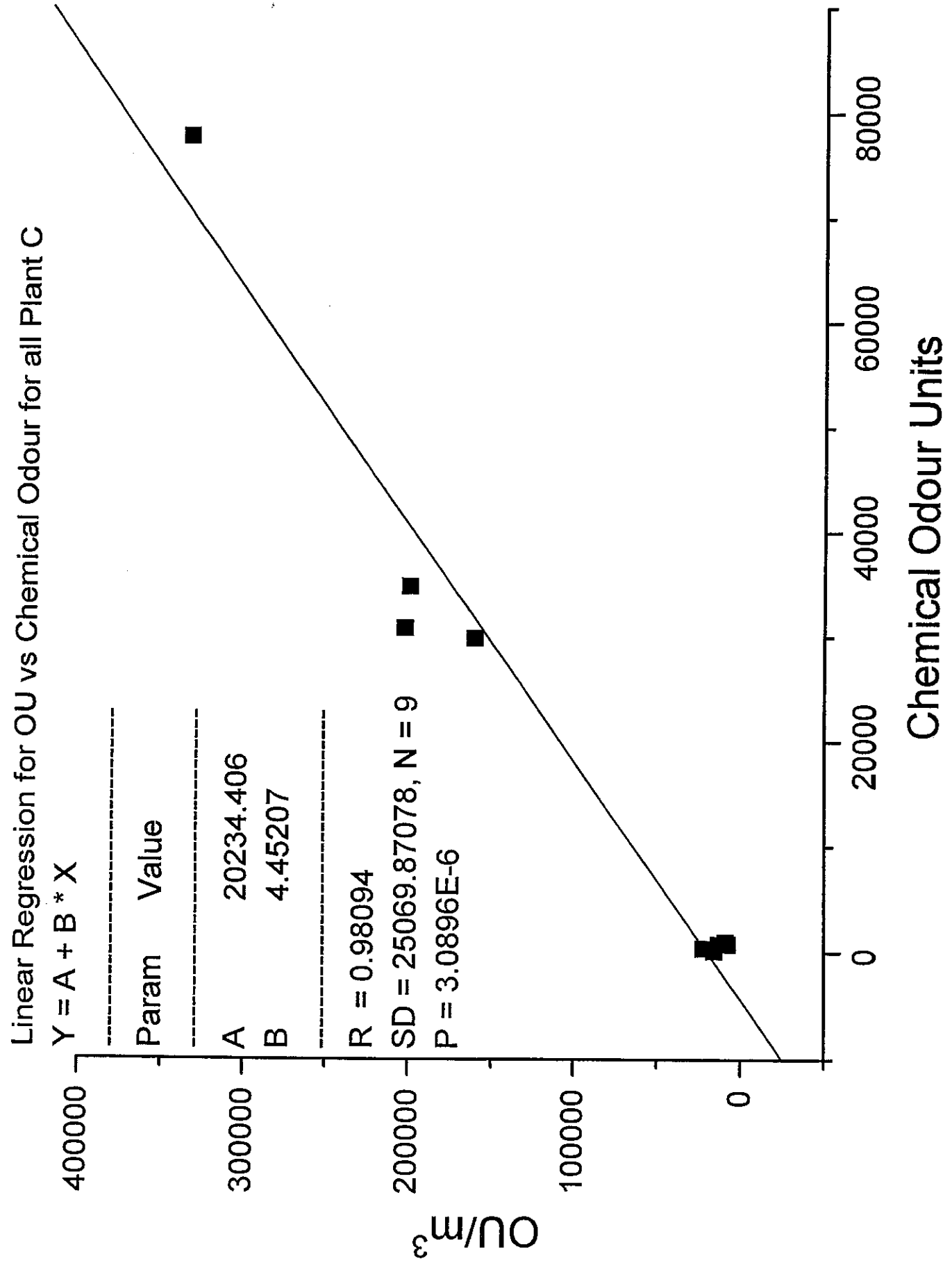

Linear Regression for OU vs Chemical Odour for Plant A, 18 Dec 1997
Y = A + B * X
Param Value
A 4197.26
B 8.7679
R = 0.54876
SD = 4968.01712, N = 4
P = 0.45124
OU/m³
14000
12000
10000
8000
6000
4000
2000
0
0
200
400
600
800
Chemical Odour Units

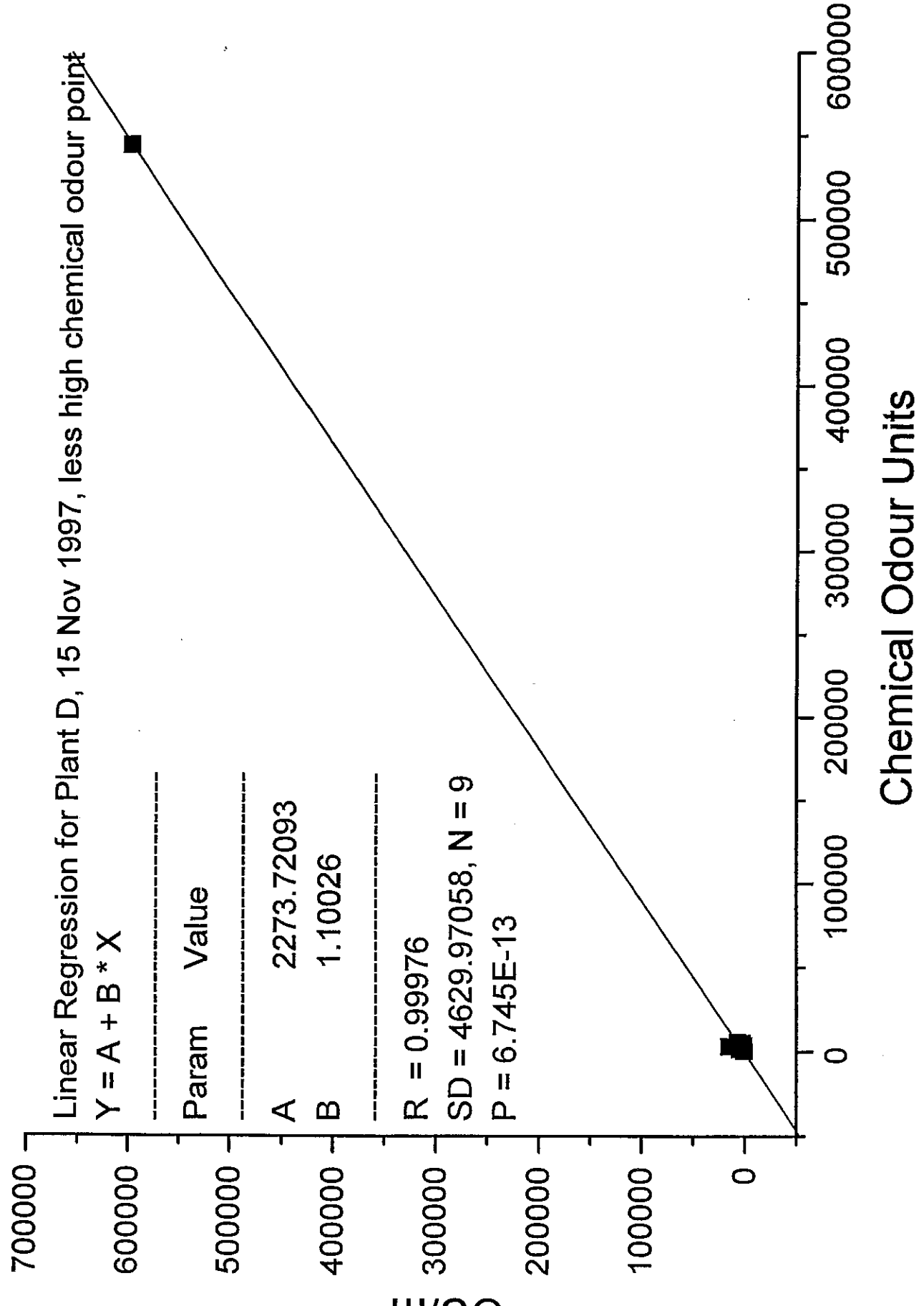

Linear Regression for selected Plant A Data
Y = A + B * X
Param Value
A 1396.585
B 2.65518
R = 0.79461
SD = 2341.96137, N = 6
P = 0.05894
OU/m³
8000
6000
4000
2000
0
0
500
1000
1500
2000
2500
3000
Chemical Odour Units

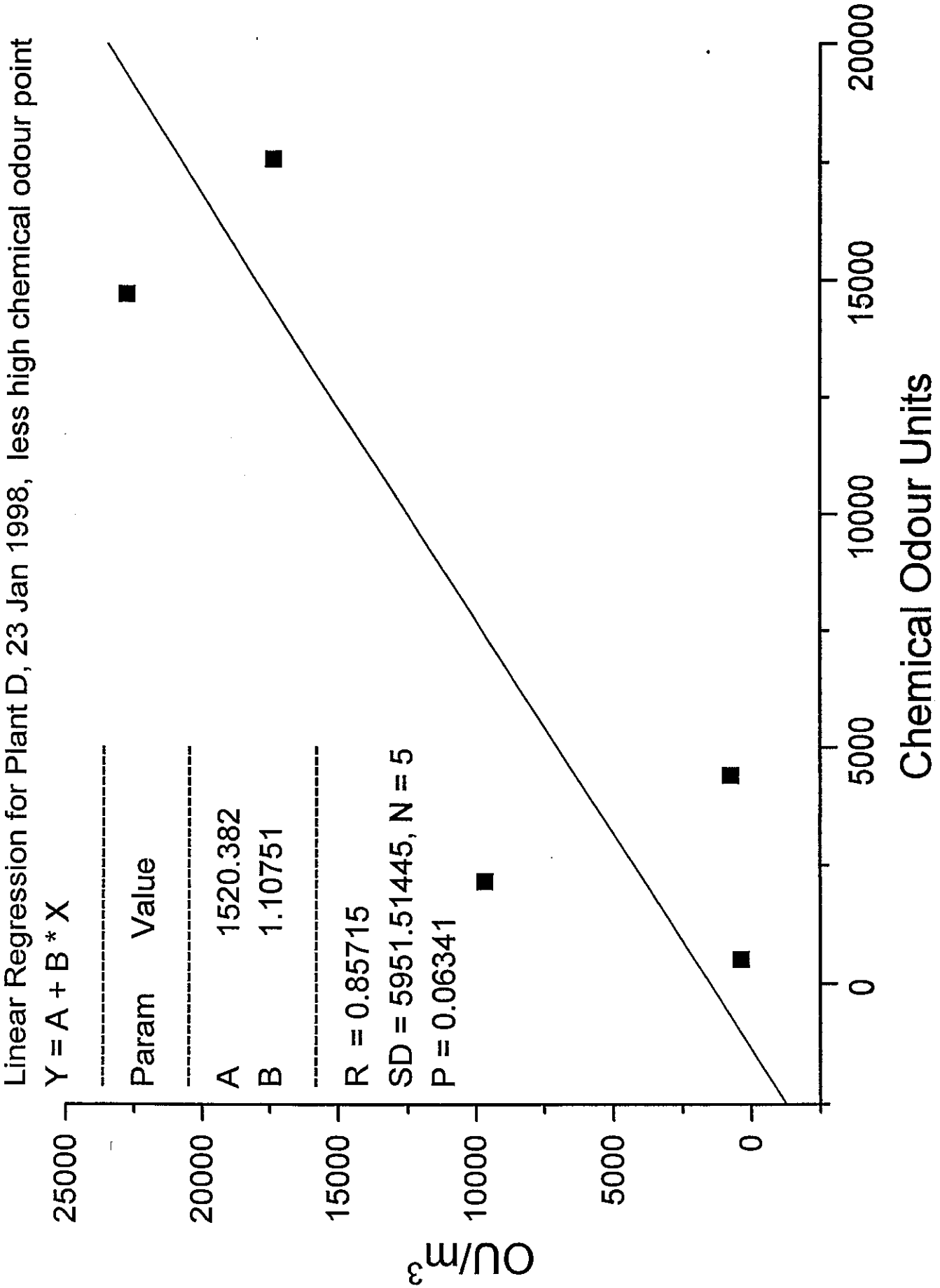

Linear Regression for Plant B (all) less high odour data
Y = A + B * X
Param Value
A 18308.509
B 0.7022
R = 0.71146
SD = 30267.73362, N = 7
P = 0.073
OU/m³
Chemical Odour Units
0
20000
40000
60000
80000
100000
120000

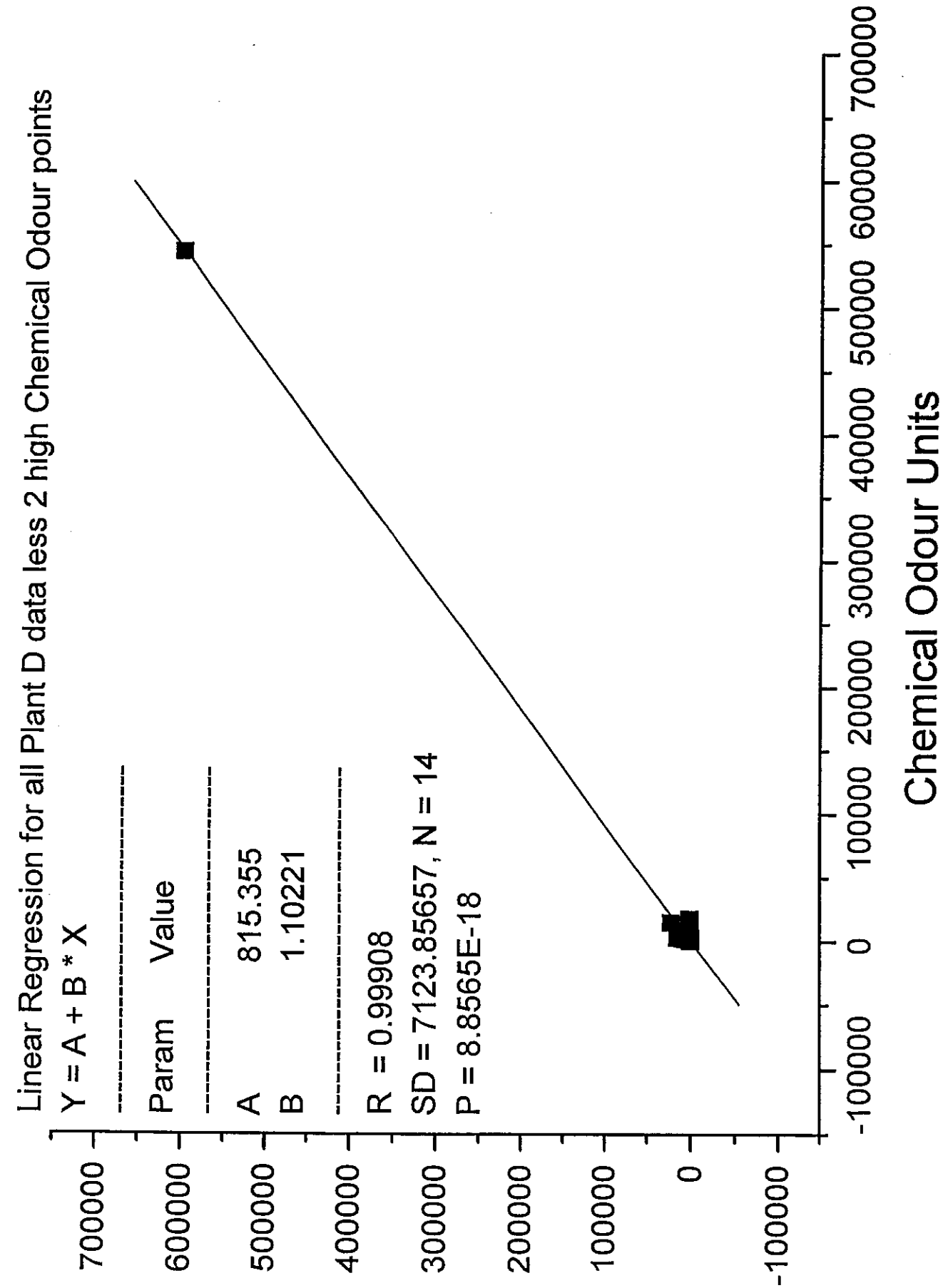

Linear Regression for OU vs Chemical Odour for Plant C, 26 Nov 1997
Y = A + B * X
Param Value
A 2912.229
B 5.91959
R = 0.98931
SD = 18156.70057, N = 4
P = 0.01069
OU/m³
200000
150000
100000
50000
0
0
5000
10000
15000
20000
25000
30000
35000
Chemical Odour Units

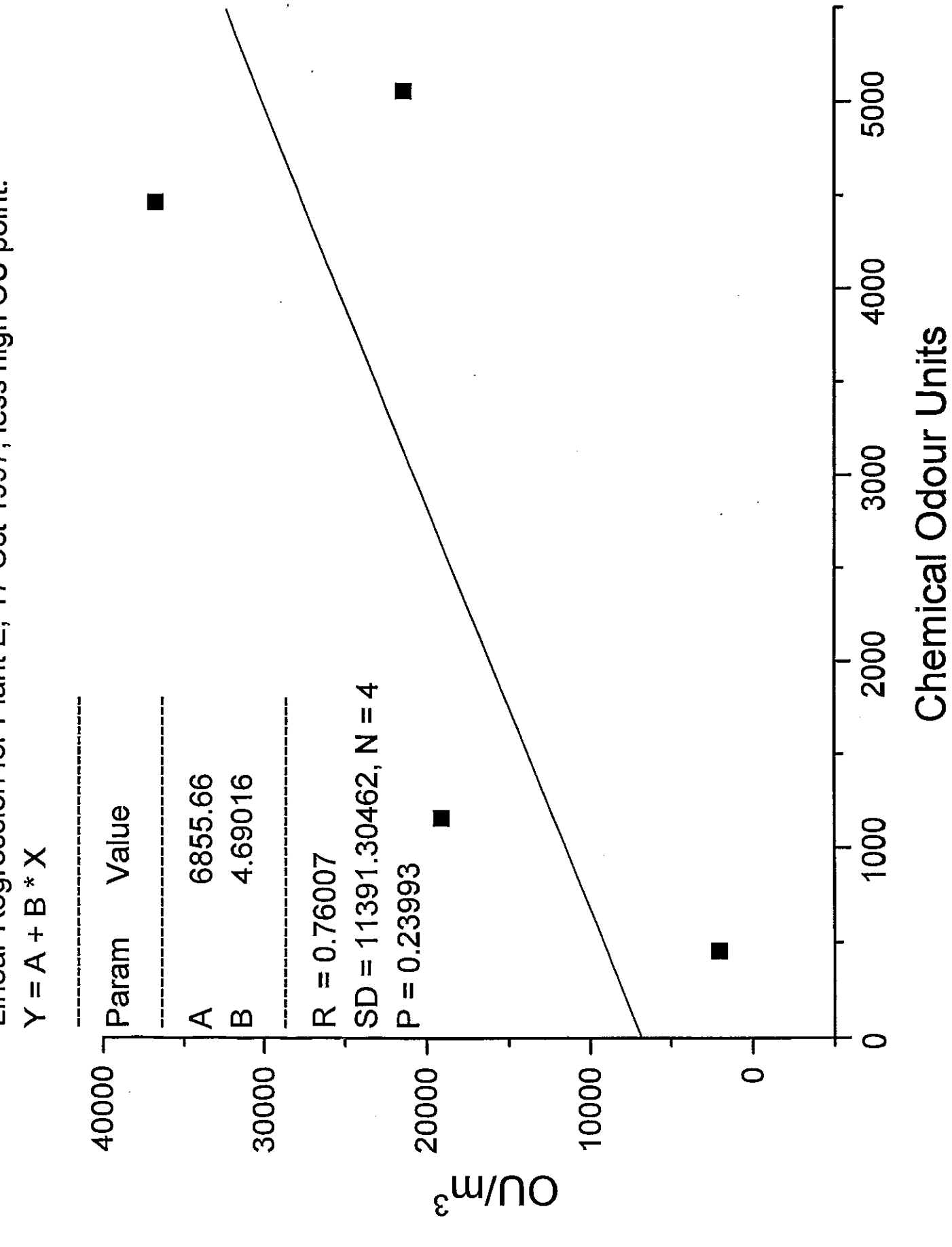

Linear Regression for OU vs Chemical Odour for Plant C, 4 Mar 1998
Y = A + B * X
Param Value
A 21193.726
B 4.21455
R = 0.99174
SD = 21516.0723, N = 5
P = 0.0009
OU/m³
350000
300000
250000
200000
150000
100000
50000
0
0
20000
40000
60000
80000
Chemical Odour Units

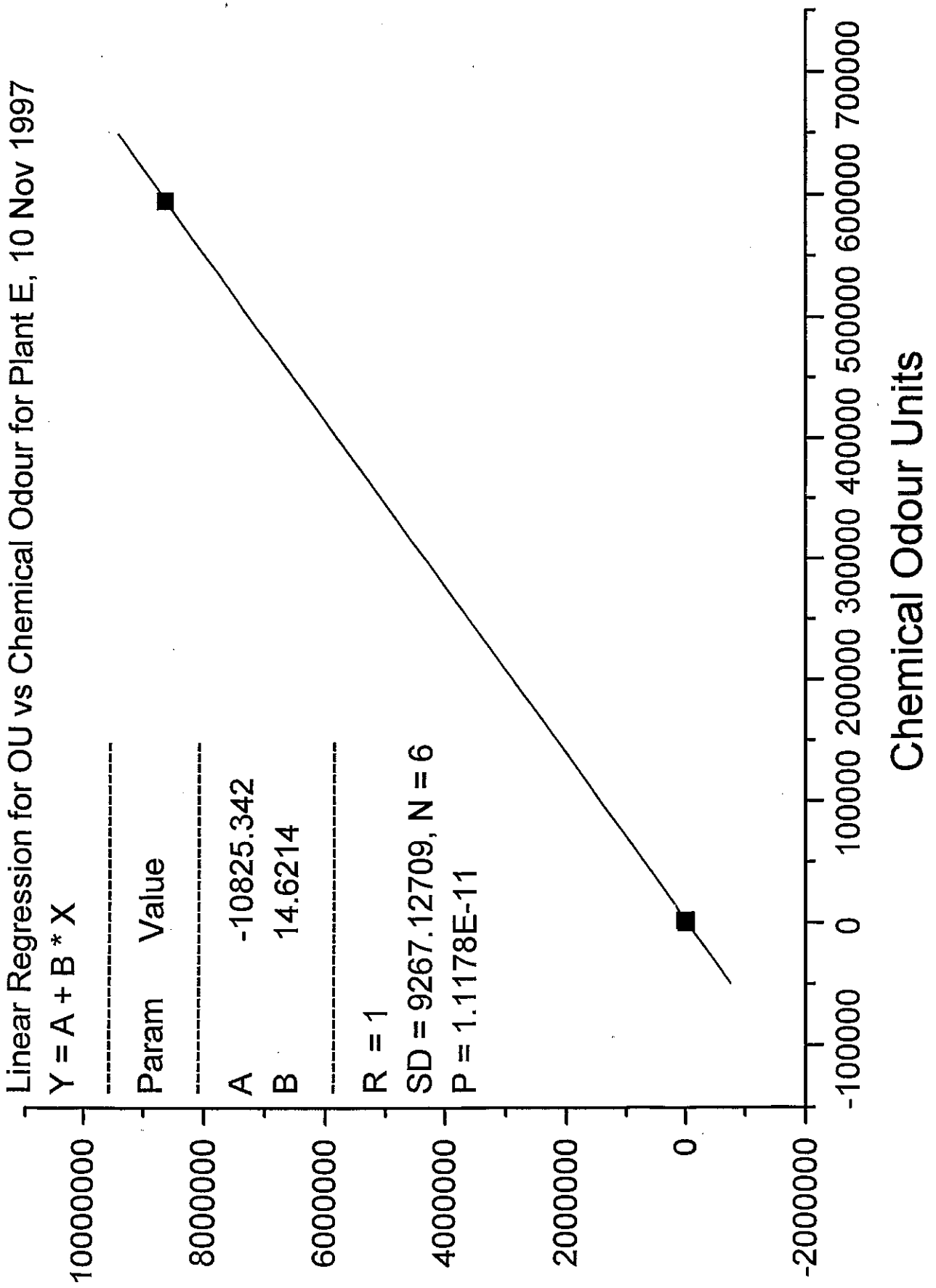

Linear Regression for OU vs Chemical Odour for all Plant C
Y = A + B * X
Param Value
A 20234.406
B 4.45207
R = 0.98094
SD = 25069.87078, N = 9
P = 3.0896E-6
OU/m³
400000
300000
200000
100000
0
0
20000
40000
60000
80000
Chemical Odour Units

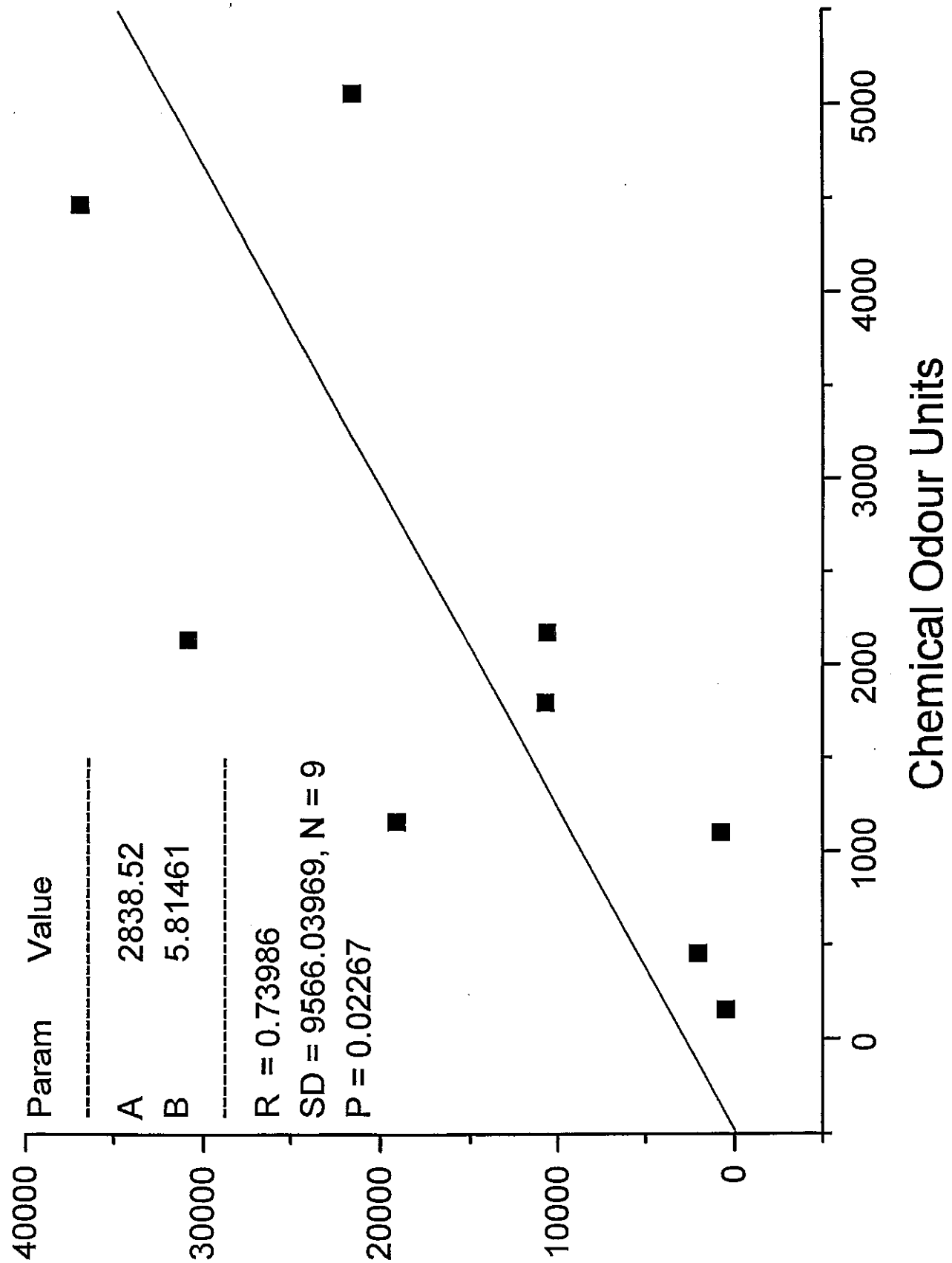

Linear Regression for Plant D, 15 Nov 1997, less high chemical odour point
Y = A + B * X
Param Value
A 2273.72093
B 1.10026
R = 0.99976
SD = 4629.97058, N = 9
P = 6.745E-13
OU/m³
700000
600000
500000
400000
300000
200000
100000
0
0
100000
200000
300000
400000
500000
600000
Chemical Odour Units


Linear Regression for Plant D, 23 Jan 1998, less high chemical odour point
Y = A + B * X
Param Value
A 1520.382
B 1.10751
R = 0.85715
SD = 5951.51445, N = 5
P = 0.06341
OU/m³
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
Chemical Odour Units


Linear Regression for all Plant D data less 2 high Chemical Odour points
Y = A + B * X
Param Value
A 815.355
B 1.10221
R = 0.99908
SD = 7123.85657, N = 14
P = 8.8565E-18
OU/m³
700000
600000
500000
400000
300000
200000
100000
0
-100000
-100000 0 100000 200000 300000 400000 500000 600000 700000
Chemical Odour Units


Linear Regression for Plant E, 17 Oct 1997, less high OU point:
Y = A + B * X
Param Value
A 6855.66
B 4.69016
R = 0.76007
SD = 11391.30462, N = 4
P = 0.23993
OU/m³
40000
30000
20000
10000
0
0
1000
2000
3000
4000
5000
Chemical Odour Units


Linear Regression for OU vs Chemical Odour for Plant E, 10 Nov 1997
Y = A + B * X
Param Value
A -10825.342
B 14.6214
R = 1
SD = 9267.12709, N = 6
P = 1.1178E-11
OU/m³
10000000
8000000
6000000
4000000
2000000
0
-2000000
-100000 0 100000 200000 300000 400000 500000 600000 700000
Chemical Odour Units


Linear Regression for all low strength Plant E data
Y = A + B * X
Param Value
A 2838.52
B 5.81461
R = 0.73986
SD = 9566.03969, N = 9
P = 0.02267
OU/m³
40000
30000
20000
10000
0
0
1000
2000
3000
4000
5000
Chemical Odour Units

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APPENDIX 5

AFISC REPORT ON ELECTRONIC NOSE ANALYSIS

EXECUTIVE SUMMARY

The aim of this project was to develop suitable methodology and assess a series of odour samples using the AromaScan and Alpha-MOS Fox 4000 systems (under standard conditions) to investigate whether the technology can discriminate between samples and to provide data for comparison with established technologies already in use.

30 samples of odour emissions from red meat processing and rendering plants from around Australia as well as some synthetic odour mixtures provided by Dr Stone (A.N.S.T.O.) were analysed using the "AromaScan" electronic aroma sensing system. A reduced set of samples were analysed using a Fox 4000 by Dr. David Fotheringham of TSE & AEC equipment suppliers

Details of sampling conditions and equipment protocols are reported.

Data generated indicates that:

- The AromaScan and Fox 4000 electronic aroma sensing systems are capable of discrimination between different odour samples taken from various meat processing plants in Australia.

- The AromaScan and Fox 4000 electronic aroma sensing systems are capable of discriminating between different concentrations of the same sample with the order of magnitude of samples represented correctly by the analysis.

- The "AromaScan" electronic aroma sensing system was capable of discriminating between some synthetic mixtures of odours with limited success on odours created from a single constituent compound. When selected synthetic odour mixtures were mapped with "authentic" odour samples they appeared to map near to where they would be expected to if they originated from an "authentic" source.

It is suggested that electronic aroma assessment shows good promise as a fast, inexpensive alternative to olfactometry and GC-MS.

Further work should continue however:

- The analysis date of samples for different techniques should be more closely co-ordinated.
- A higher number of sample replicates should be performed.
- Analysis should span over a longer time frame to assess stability of technique.
- The Fox 4000 machine should be used in subsequent work due to its greater sensitivity, less susceptibility to differences in humidity and better control over sample injection.

CONFIDENTIAL PROJECT REPORT
INVESTIGATION OF ODOUR EMISSIONS FROM RED MEAT PROCESSING AND RENDERING PLANTS USING ELECTRONIC NOSE TECHNOLOGY

FOR Meat Research Corporation
Dr. Mike Johns

INTRODUCTION

The Meat Research Corporation established a project with Mr Terry Schulz of CH2M-HILL and Dr David Stone of the Australian Nuclear Science and Technology Organisation (ANSTO) to investigate the application of new methods of odour measurement for the analysis and fingerprinting of meat industry odour streams. They conducted the analysis of odours sampled from five sites across Australia, including red meat processing and rendering plants, using GC-MS and dynamic olfactometry. There is also particular interest in assessing the potential of Electronic Nose technology for this application. The data from the three techniques will provide valuable information to the meat industry for the future.

Electronic Nose technology is a rapidly developing field based on the general principle that the test odour is passed over an array of electronic sensors that respond in a characteristic manner to the material to which they are exposed. In the early instruments the sensors were of special polymeric materials; a number of other materials, such as metal oxides, are now being developed for particular applications. Some of these have particular sensitivity to a limited number of molecular types, some are of a more general application. The AromaScan instrument utilises the polymeric sensor system and has been found to be successful in a wide range of applications. The Alpha-MOS FOX 4000 instrument uses metal oxide sensors and has also been found to be very successful.

It is important to realise that the sensors do not analyse the sample in the traditional sense, but produce a characteristic response (as an electrical signal) or fingerprint for a particular sample. That signal may then be used as a reference for comparison with subsequent sample signals. In effect the instrument is "trained" to recognise the signal responses of the initial samples; and these are then compared with further measurements on the same sample, in which case the fingerprint should be identical (or very similar); or on different samples, in which case different fingerprints should be recorded. Advanced data handling and neural network systems are now available for the analysis and presentation of the results.

The technique has been successfully developed over a wide range of industrial applications. In the food industry it is being used for such applications as sample quality control, the detection of rancidity in oils, the detection of off-odours in meat and fish, in the ageing of cheese, and in monitoring the source of olive oil.

PROJECT AIM

The aim of this project is to develop suitable methodology and assess a series of odour samples using the AromaScan and the FOX 4000 (under standard conditions) to investigate whether the technology can discriminate between samples and to provide data for comparison with the more established technologies already being used.

METHODS

Mechanism

The AromaScan is an "electronic nose" which utilises the reaction of aroma volatile compounds passing over a polymer sensor array to produce an electrical current from which a "digital fingerprint" is made of a particular aroma.

Conducting polymers are coated onto an electrode. When a voltage is passed across the electrode, a current passes through the semi conducting polymer. When volatile compounds flow over the sensor, a series of physical interactions occur. A dynamic equilibrium is set up as volatiles are constantly adsorbed and desorbed at the sensor surface. The addition of these compounds to the surface affects the current passing through the sensor by altering the flow of the electrons in the system. The current, and therefore the resistance, is modified; thus a simple chemoresistive measurement can be made. The magnitude of this signal is representative of the amount and type of volatiles present at the surface. In many samples, several hundred different volatiles may be present in the headspace; therefore one individual sensor would be unable to detect minor changes in volatile composition. However, by the combination of several sensors into an array, with each sensor having differing selectivity's to different classes of compounds, a more complete pattern or aroma profile may be built up that should be characteristic of a particular sample. The Aromascan has 32 polymer sensors. An aroma profile for a rendering plant odour emission is shown in Figure 1.

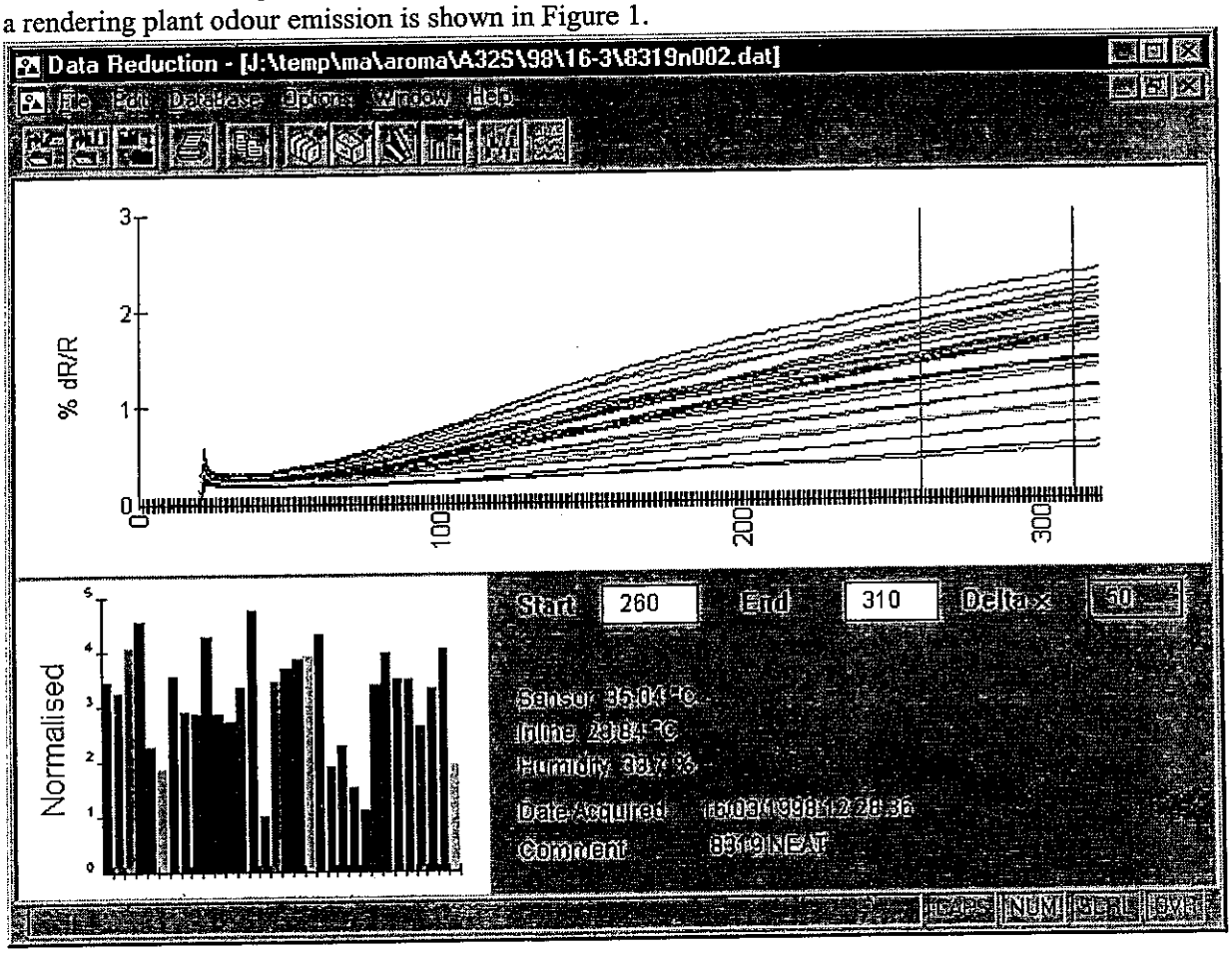


Figure 1.

As can be seen from the diagram each line represents a single sensor which shows the electrical output of the sensor over the time of the exposure to the sample. A "slice" of this data is then selected which is averaged over the time of the slice for each sensor to produce a "fingerprint". This data is then displayed as a 2 or 3 dimensional plot which permits the visual comparison of different samples.

The Fox 4000 is a similar machine which uses 18 metal oxide sensors and records and analyses the data in a similar way to the AromaScan machine. The analysis of samples on the Fox 4000 was performed by Dr. David Fotheringham of TSE & AEC equipment suppliers. Conditions of analysis are not reported here.

Sample Preparation

Air samples were received in collection bags. Samples were injected neat or diluted with air (instrument grade) at 30% relative humidity as the analysis required. Samples were incubated at 25° C for 20 minutes previous to injection.

Sample Injection and Data Collection

The sample bag was connected to the inlet port of the "AromaScan A32S analyser".
The data collection parameters were as follows.

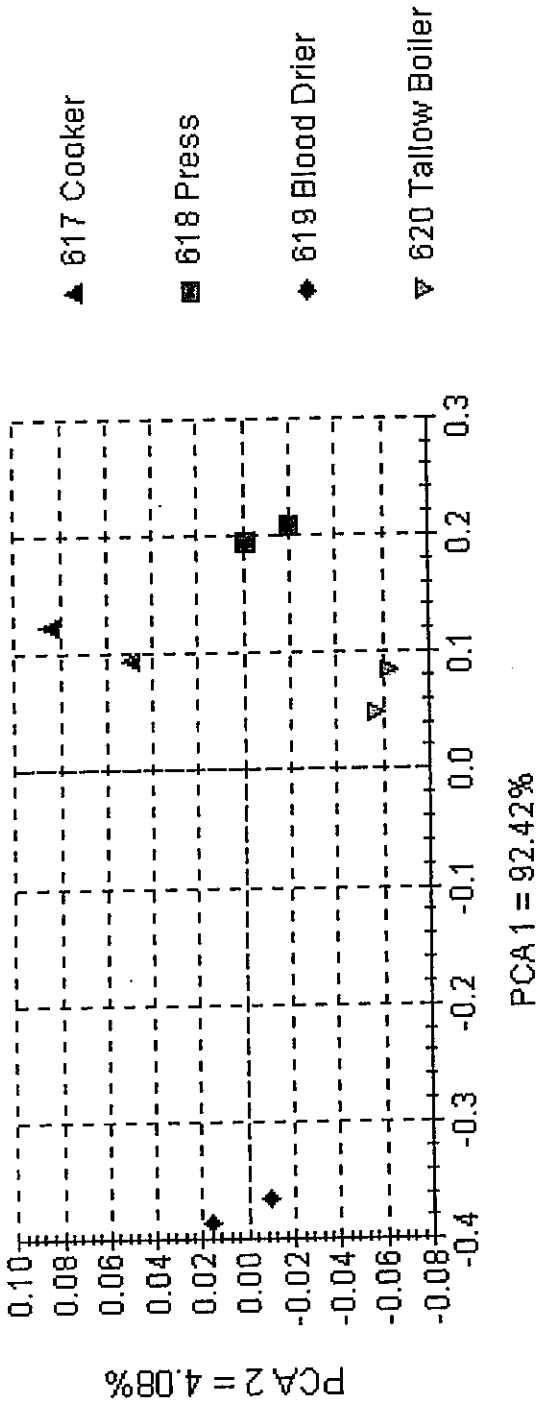
Reference	20 sec
Sample	300 sec
Wash	60 sec
Reference	1200 sec
Temperature	25° C
Reference RH%	20% @ 30° C (33% offset below sample humidity)

Data Selection

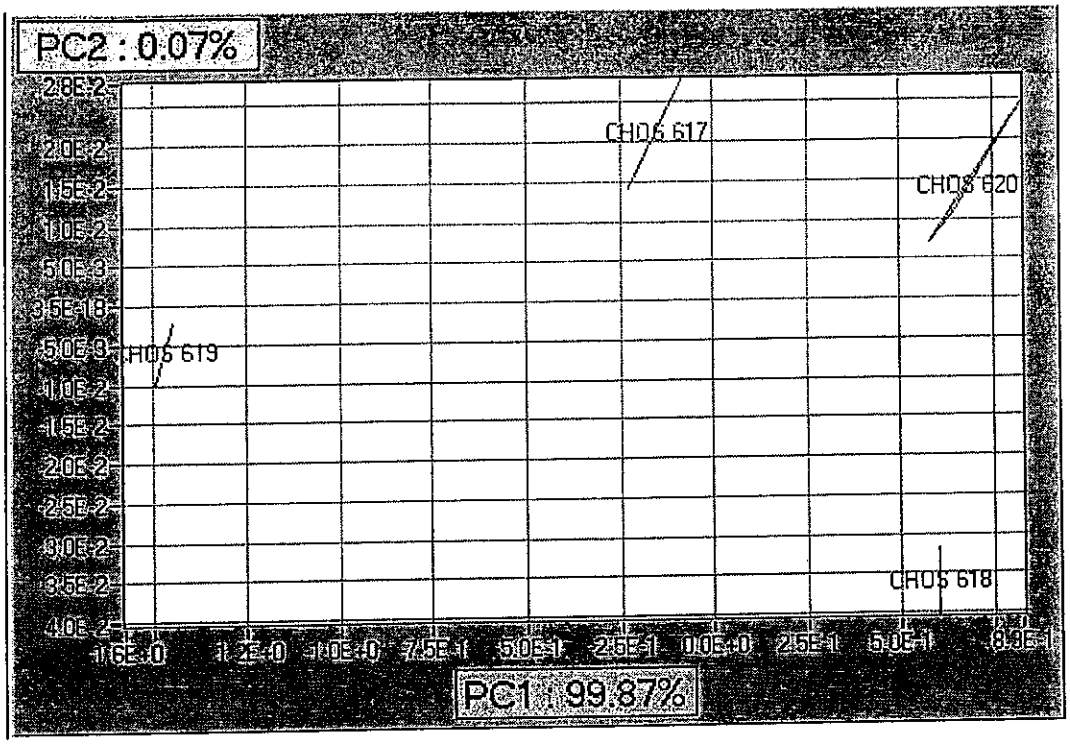
Data from the time period 260-310 sec was averaged and used for principle component analysis to allow mapping of the samples

Analysis Technique

Principle component analysis was used to reduce the data set to two dimensions in order to more easily visualise the relationships between the samples. Principle component analysis is an unsupervised technique, ie it does not rely on assigning samples to groups, all samples are treated as if they were unrelated.



Map 1: Principle component analysis of samples from Plant B analysed using the AromaScan

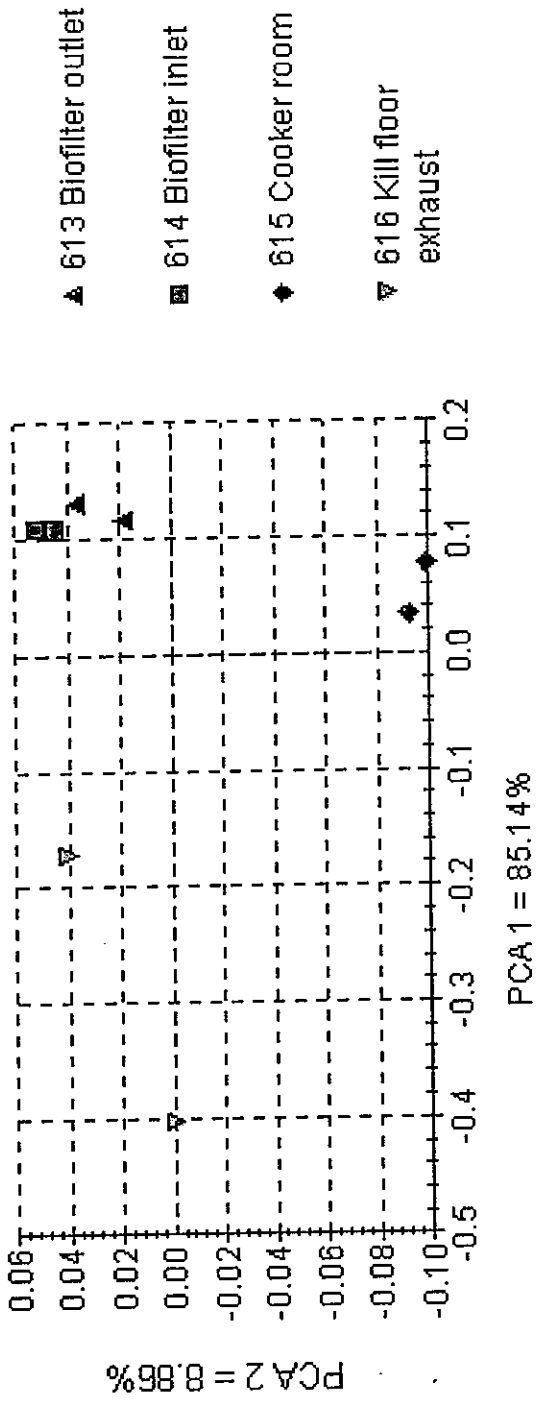


Map 2: Principle component analysis of samples from Plant B analysed using the Fox 4000

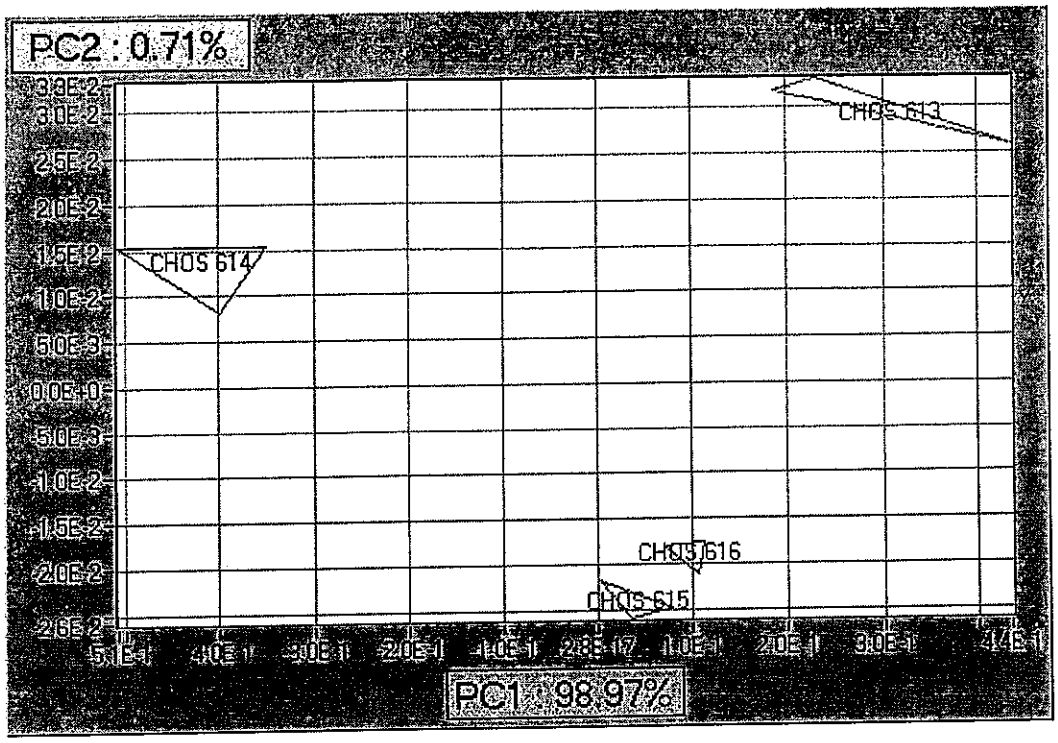
	Sum Sulphurs	*Sum Aldehydes*	*Sum others*	*TOTAL Odour*	*ODU*	*ASPC1*	*ASPC2*
Sum Sulphurs	1.000						
Sum Aldehydes	-0.072	1.000					
Sum others	-0.584	0.829	1.000				
TOTAL Odour	0.245	0.949	0.622	1.000			
ODU*	0.758	0.520	0.070	0.745	1.000		
ASPC1#	-0.016	0.982	0.819	0.950	0.609	1.000	
ASPC2#	-0.313	-0.131	0.239	-0.225	-0.037	0.021	1.000

*Olfactometry results
AromaScan principle component

Table 1: Correlation matrix of GC-MS, Olfactometry, and AromaScan data for Plant B.



Map 3: Principle component analysis of samples from Plant A analysed using the AromaScan.

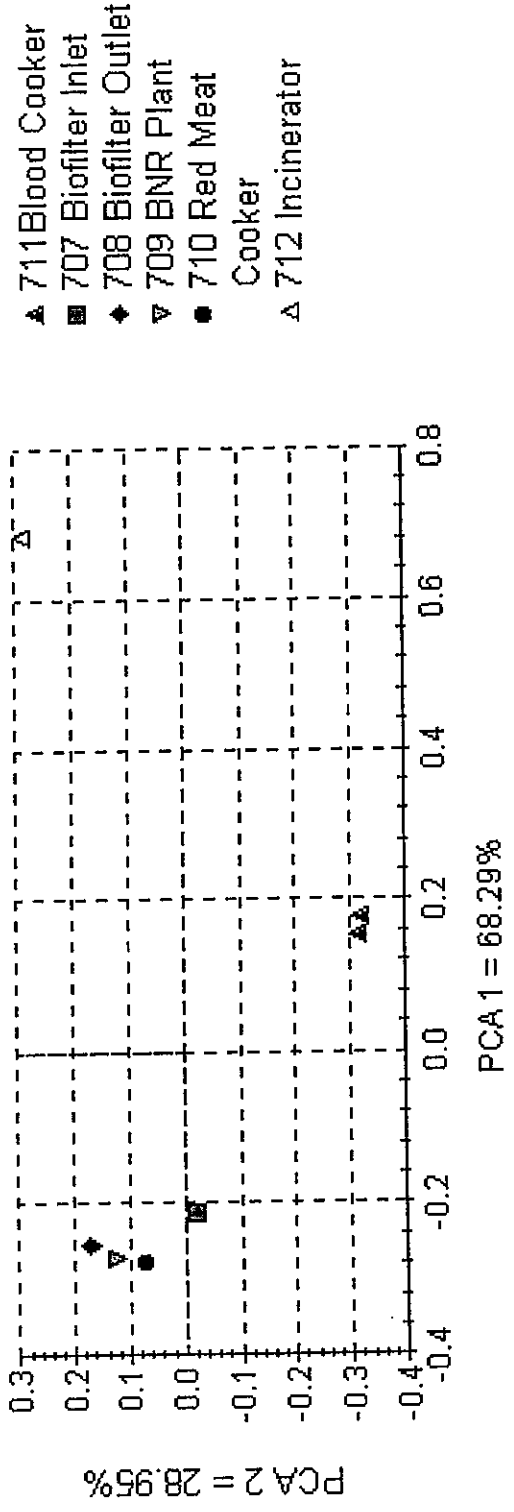


Map 4: Principle component analysis of samples from Plant A analysed using the Fox 4000.

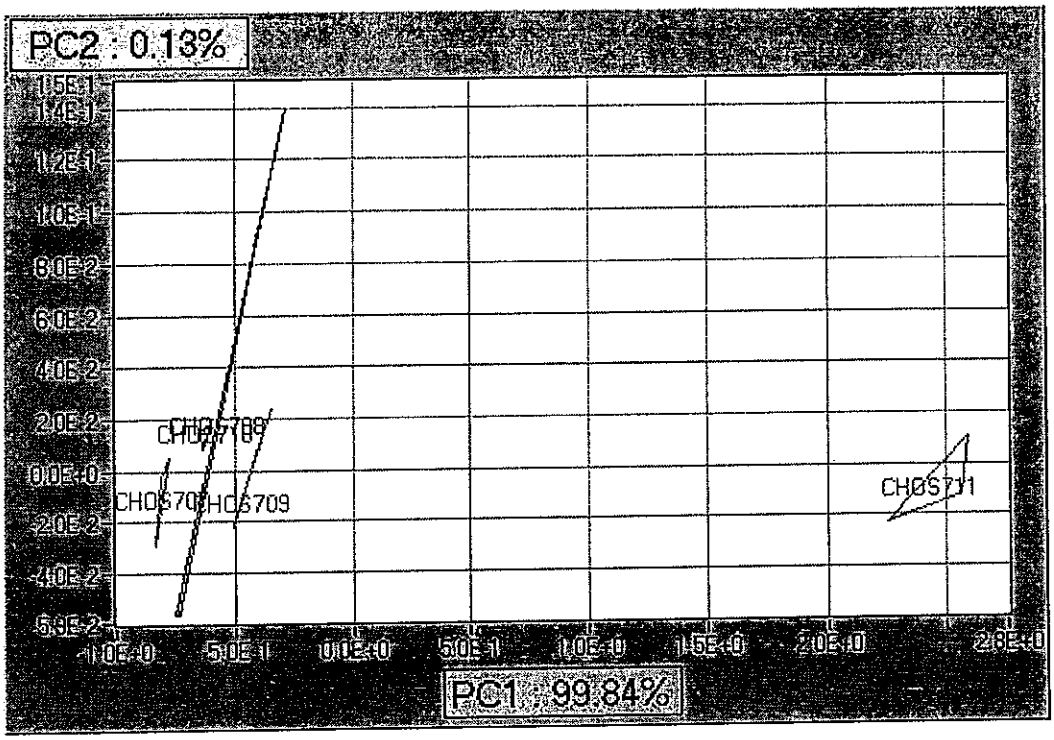
	Sum Sulphurs	*Sum Aldehydes*	*Sum others*	*TOTAL Odour*	*ODU*	*ASPC1*	*ASPC2*
Sum Sulphurs	1.000						
Sum Aldehydes	0.563	1.000					
Sum others	-0.087	-0.335	1.000				
TOTAL Odour	0.775	0.958	-0.250	1.000			
ODU*	0.081	0.648	0.377	0.549	1.000		
ASPC1#	0.149	0.437	0.672	0.420	0.930	1.000	
ASPC2#	0.893	0.873	-0.270	0.973	0.372	0.289	1.000

*Olfactometry results
AromaScan principle component

Table 2: Correlation matrix of GC-MS, Olfactometry, and AromaScan data from Plant A.



Map 5: Principle component analysis of samples from Plant D using the AromaScan.

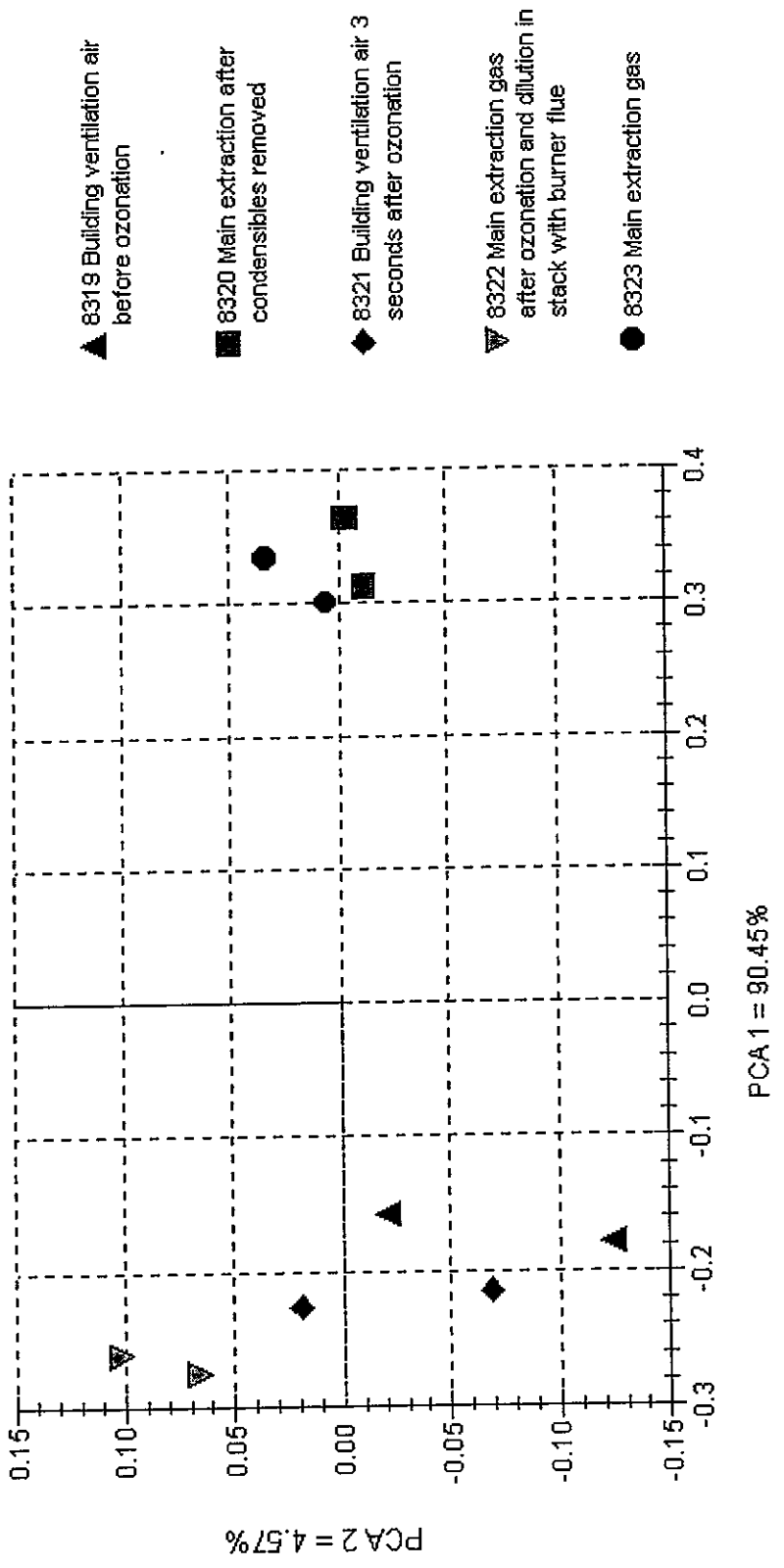


Map 6: Principle component analysis of samples from Plant D using the Fox 4000.

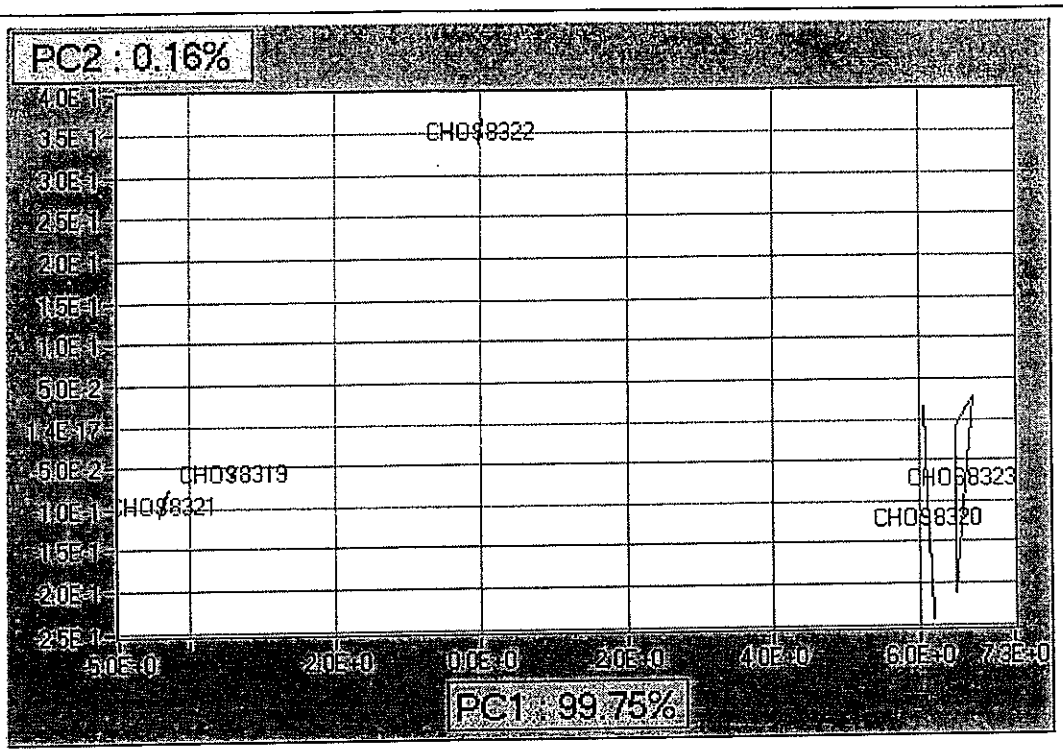
	Sum Sulphurs	*Sum Aldehydes*	*Sum others*	*TOTAL Odour*	*ODU*	*ASPC1*	*ASPC2*
Sum Sulphurs	1.000						
Sum Aldehydes	1.000	1.000					
Sum others	0.999	0.999	1.000				
TOTAL Odour	1.000	1.000	0.999	1.000			
ODU*	0.788	0.789	0.812	0.788	1.000		
ASPC1#	0.901	0.898	0.905	0.900	0.654	1.000	
ASPC2#	0.522	0.527	0.501	0.523	0.448	0.118	1.000

*Olfactometry results
AromaScan principle component

Table 3: Correlation matrix of GC-MS, Olfactometry, and AromaScan data for Plant D.



Map 7: Principle component analysis of samples from Plant C using the AromaScan

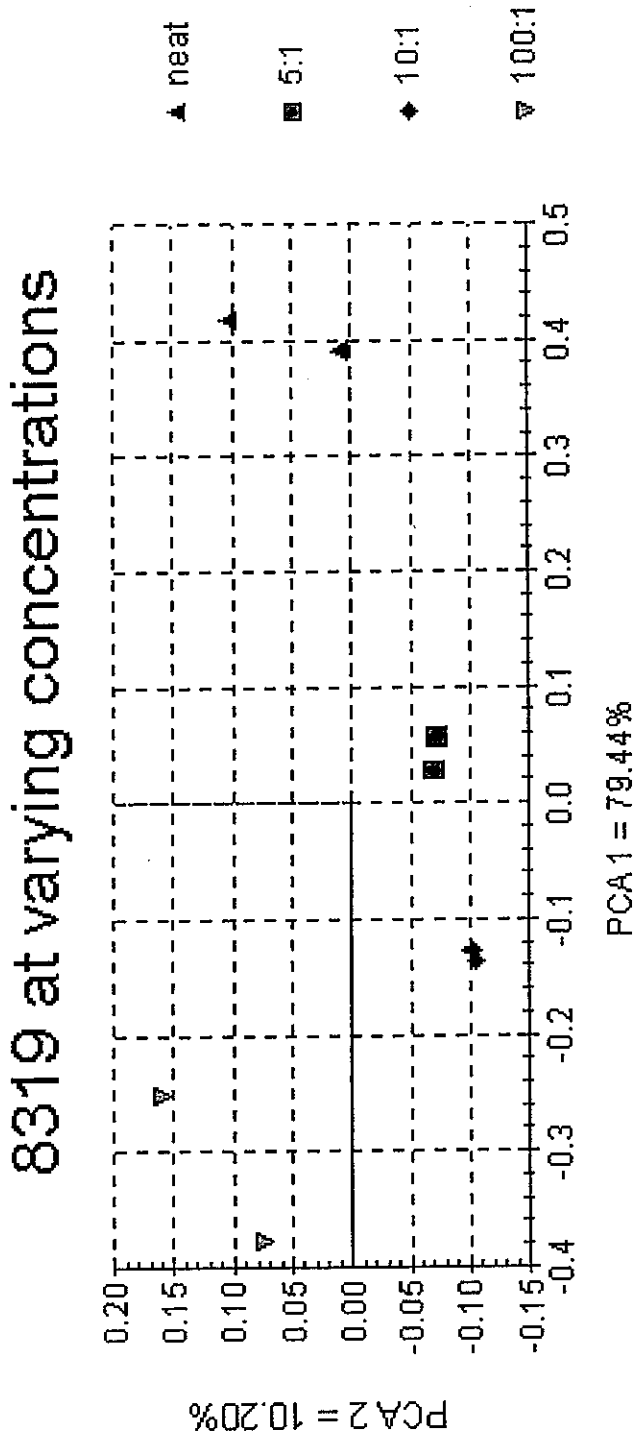


Map 8: Principle component analysis of samples from Plant C using the Fox 4000

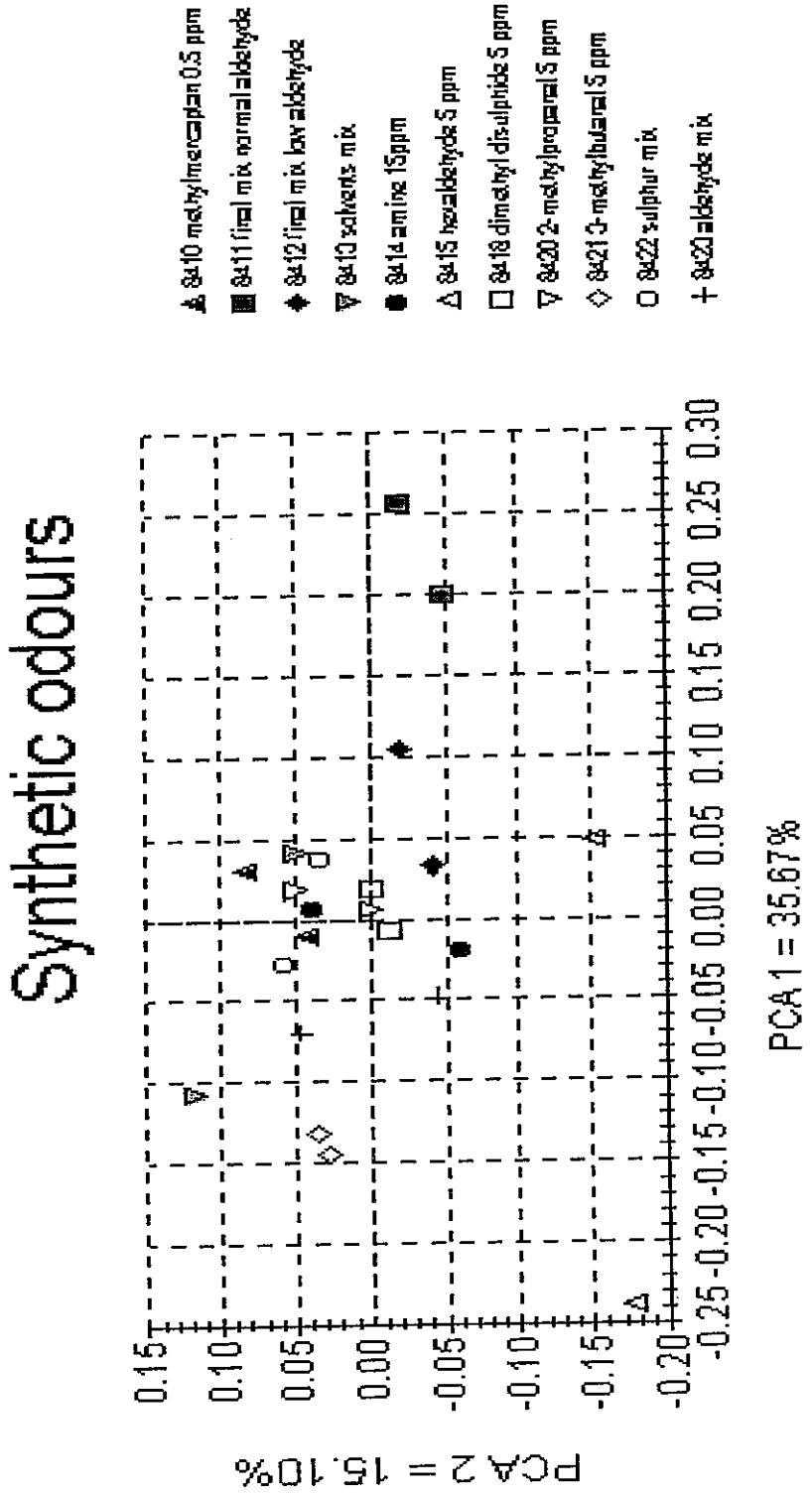
	Sum Sulphurs	*Sum Aldehydes*	*Sum others*	*TOTAL Odour*	*ODU*	*ASPC1*	*ASPC2*
Sum Sulphurs	1.000						
Sum Aldehydes	0.861	1.000					
Sum others	0.952	0.975	1.000				
TOTAL Odour	0.997	0.896	0.972	1.000			
ODU*	0.980	0.943	0.992	0.992	1.000		
ASPC1#	0.845	0.989	0.959	0.879	0.933	1.000	
ASPC2#	0.235	0.189	0.233	0.232	0.192	0.045	1.000

*Olfactometry results
AromaScan principle component

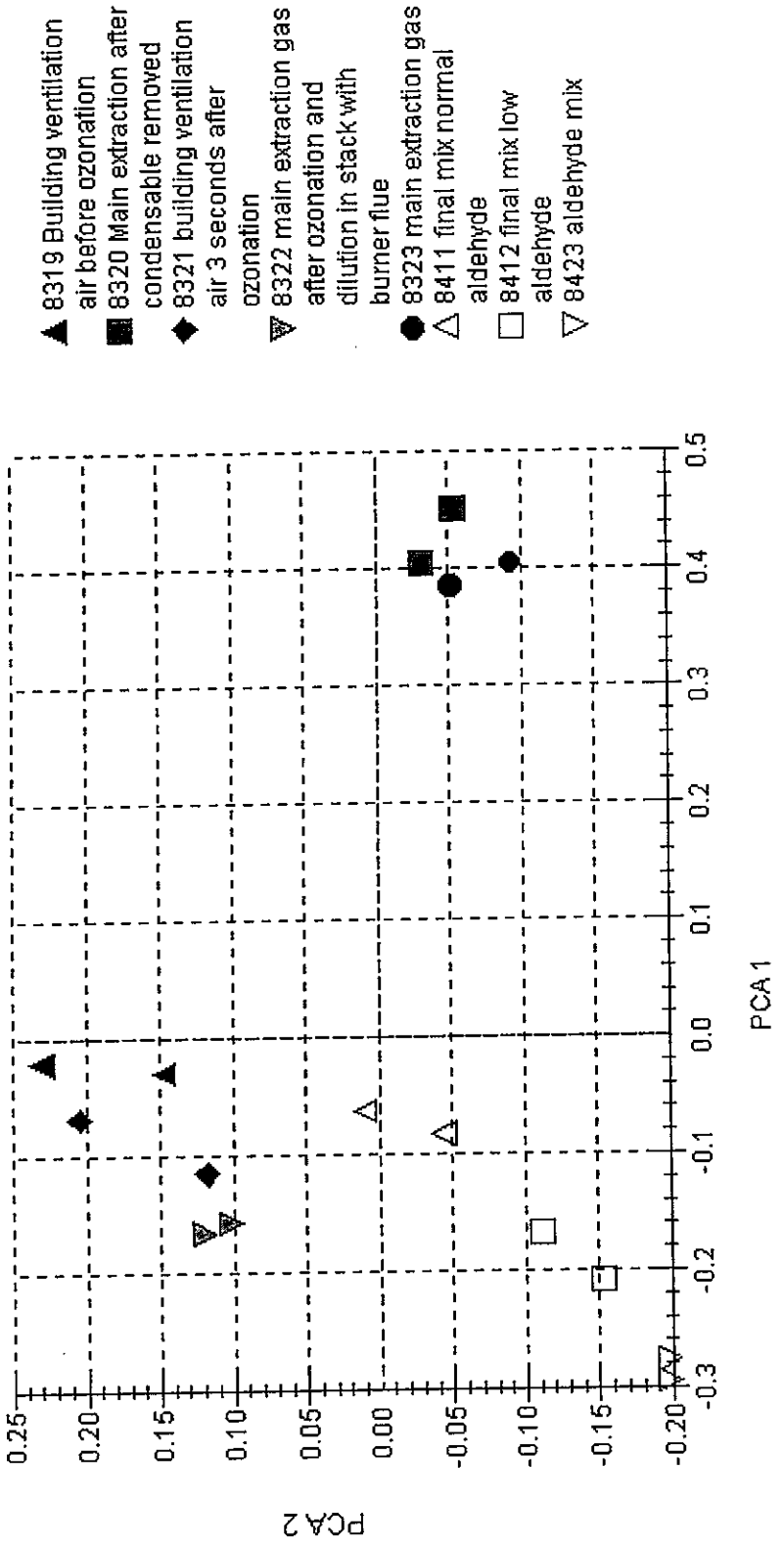
Table 4: Correlation matrix of GC-MS, Olfactometry, and AromaScan data for Plant C.



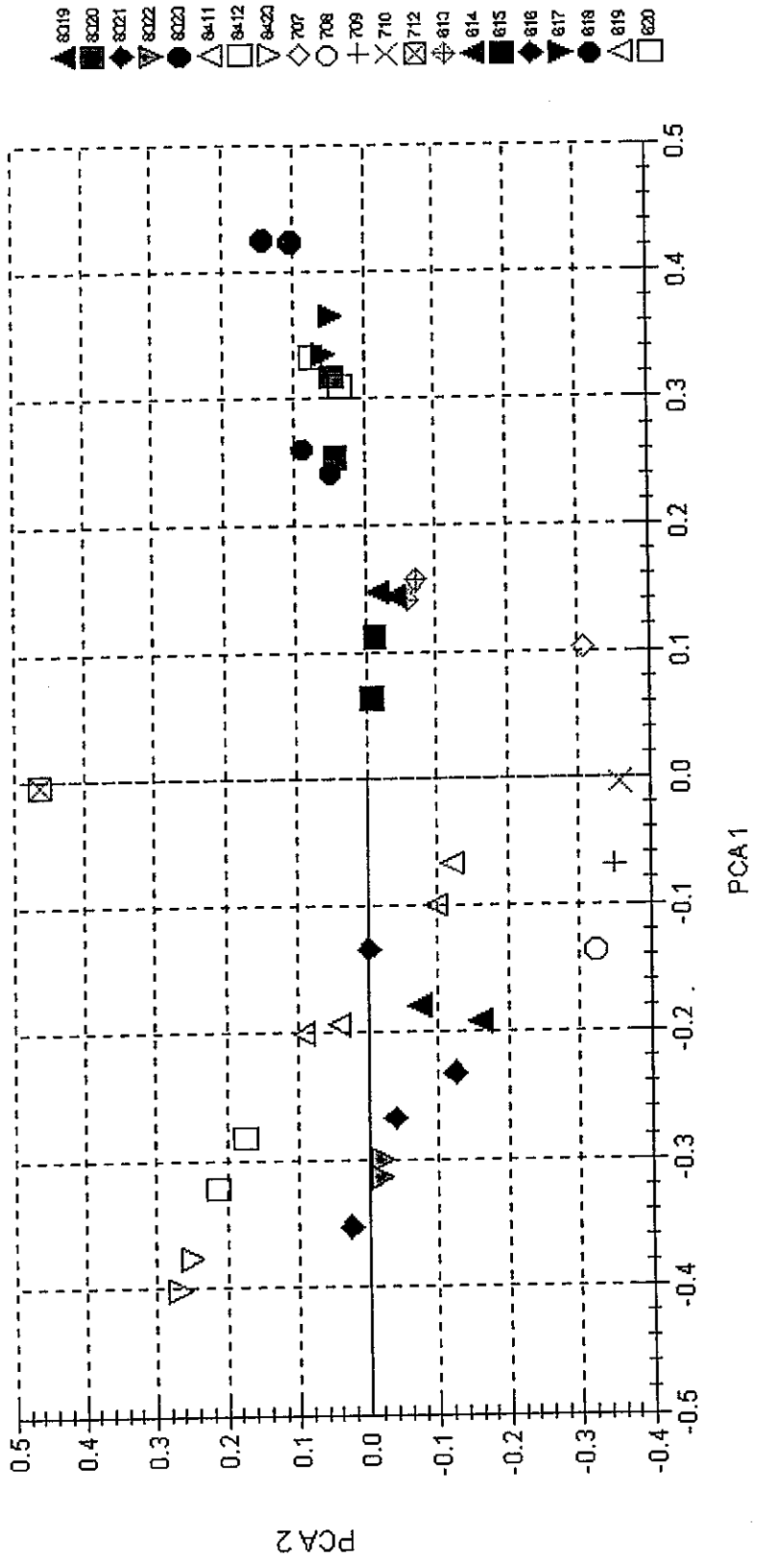
Map 9: Principle component analysis of sample 8319 at various dilutions using the AromaScan



Map 10: Principle component analysis of synthetic samples using the AromaScan



Map 11: Principle component analysis of samples from Plant C & synthetic aldehyde samples using the AromaScan



Map 12: Principle component analysis of all samples using the AromaScan .

	Sum Sulphurs	Sum Aldehydes	Sum others	TOTAL Odour	ODU	ASPC1	ASPC2
	0.980	0.943	0.992	0.992	1.000	0.933	0.192
	0.758	0.520	0.070	0.745	1.000	0.609	-0.037
	0.081	0.648	0.377	0.549	1.000	0.930	0.372
	0.788	0.789	0.812	0.788	1.000	0.654	0.448
average	0.652	0.725	0.563	0.768	1.000	0.782	0.243

Table 5: Comparison of correlations for olfactometry vs GC-MS and Aromascan for all sites tested.

Discussion

When interpreting the maps it is important to note that the samples are mapped to show greatest differences whether they be quantitative or qualitative. In general for these samples it can be said that the x axis relates more closely to concentration of odours and the y axis relates to some qualitative measure.

The AromaScan (Map 9) and the Fox 4000 (data not shown) can discriminate between different concentrations of the same sample indicating that it may be possible to use electronic aroma sensing to track the concentration of odour from a particular source. The latest version of the analysis software includes a concentration calibration to allow simple concentration determination.

Some samples show a high level of variation between the replicates which may be due to leakage during sampling. This study was intended only to be a preliminary assessment of the technology with the emphasis on testing more samples rather than more replicates of the same samples and it is assumed that any further work would involve a higher number of replicates to allow a measure of intra-sample variability. Since this work was performed Food Science Australia has acquired an autosampler and conditioning system for the FOX 4000 which automates all sample injection parameters. Work on other samples has shown the autosampler to improve the intra-sample variability by at least an order of magnitude.

Tables 1-4 show the level of correlation between the different analysis techniques. Table 5 shows when correlating with olfactometer results the AromaScan principle component 1 has the highest average correlation over the four sites. When looking at this data it is important to take into account that there are some data sets (ie Plant C – Map 7) where the samples are polarised, ie. a group of low concentration samples and a group of high concentration samples rather than a progression of concentrations. When performing correlations one or a few samples which are much higher or lower in concentration will act as a high leverage point and may result in a biased analysis.

It is interesting to note that synthetic samples manufactured by Dr. David Stone plotted quite near samples they were designed to emulate as shown in Map 11. This indicates that the electronic nose classifies them in a similar manner and that these samples may be able to be used as a synthetic control odour

Map 12 plots all samples on the same map which indicates, in general, higher concentrations on the right side of the map. When we start comparing sample sets against olfactometer results some of the data does not plot where we would expect. A most likely explanation is that the samples tested by olfactometry and GC-MS were analysed a day or so after collection whereas some of the samples tested by electronic aroma sensing were greater than a month old. It would be very difficult to predict

the effect on olfactometry or GC-MS results by the time the electronic analysis was done. However relative to each other samples in a set give correct magnitude differences.

The data from the Fox 4000 machine shows good discrimination of the samples but again differences between sampling time and testing make it difficult to compare with the other techniques. Food Science Australia has spent the last 4 months evaluating the Fox 4000 system on various sample matrices and would recommend that further work be performed on a Fox 4000 due to its greater sensitivity, less susceptibility to differences in humidity and better control over sample injection.

CONCLUSIONS

This series of analyses show that the AromaScan and Fox 4000 electronic aroma sensing systems are capable of discrimination between different odour samples taken from various meat processing plants in Australia. The discrimination appears to correlate in a broad sense with olfactometry results on the same samples.
The AromaScan and Fox 4000 electronic aroma sensing systems are capable of discriminating between different concentrations of the same sample with the order of magnitude of samples represented correctly by the analysis.
The AromaScan electronic aroma sensing systems was capable of discriminating between some synthetic mixtures of odours with limited success on odours created from a single constituent compound (samples not tested on Fox 4000). When selected synthetic odour mixtures were mapped with "authentic" odour samples they appeared to map near to where they would be expected to if they originated from an "authentic" source.
Based on the work done for this project electronic aroma sensing technology shows good promise as a fast, relatively inexpensive semi-analytical technique which can discriminate both semi-quantitatively and qualitatively between environmental samples of meat processing plant odours.

FURTHER WORK

This series of analyses show clearly that electronic aroma sensing discriminates both quantitative and qualitative attributes of rendering odour samples. Due to the inability to test fresh samples it was not possible to compare different sets of samples taken over time to assess the longer term correlation between the methods used. In addition the recent availability of a Fox 4000 system and an autosampler has shown greatly enhanced repeatability and discrimination.
It is suggested that electronic aroma assessment shows good promise as a fast, inexpensive alternative to olfactometry and GC-MS.
Further work should continue however:

- The analysis date of samples for different techniques should be more closely co-ordinated.
- A higher number of sample replicates should be performed.
- Analysis should span over a longer time frame to assess stability of the technique.
- The Fox 4000 instrument should be used in subsequent work due to its greater sensitivity, less susceptibility to differences in humidity and better control over sample injection.

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